giotto

esa's mission to halley's comet

B
F
H
M
A
E
Q
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G
I
S
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any other diameter as QGS and its tangent
= H2A and ΔB2&, = HPS = B2PS
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FI = PIMH.
ariane
V14
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Micha

ariane V14

KOUROU – JULY 1985

giotto

esa's mission to halley's comet

esa

arianespace

cnes

BRITISH AEROSPACE

ARIANE V 14

GIOTTO

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CHAPTER 1

SPECIFIC DATA ON FLIGHT V 14

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2. V14 Key personnel

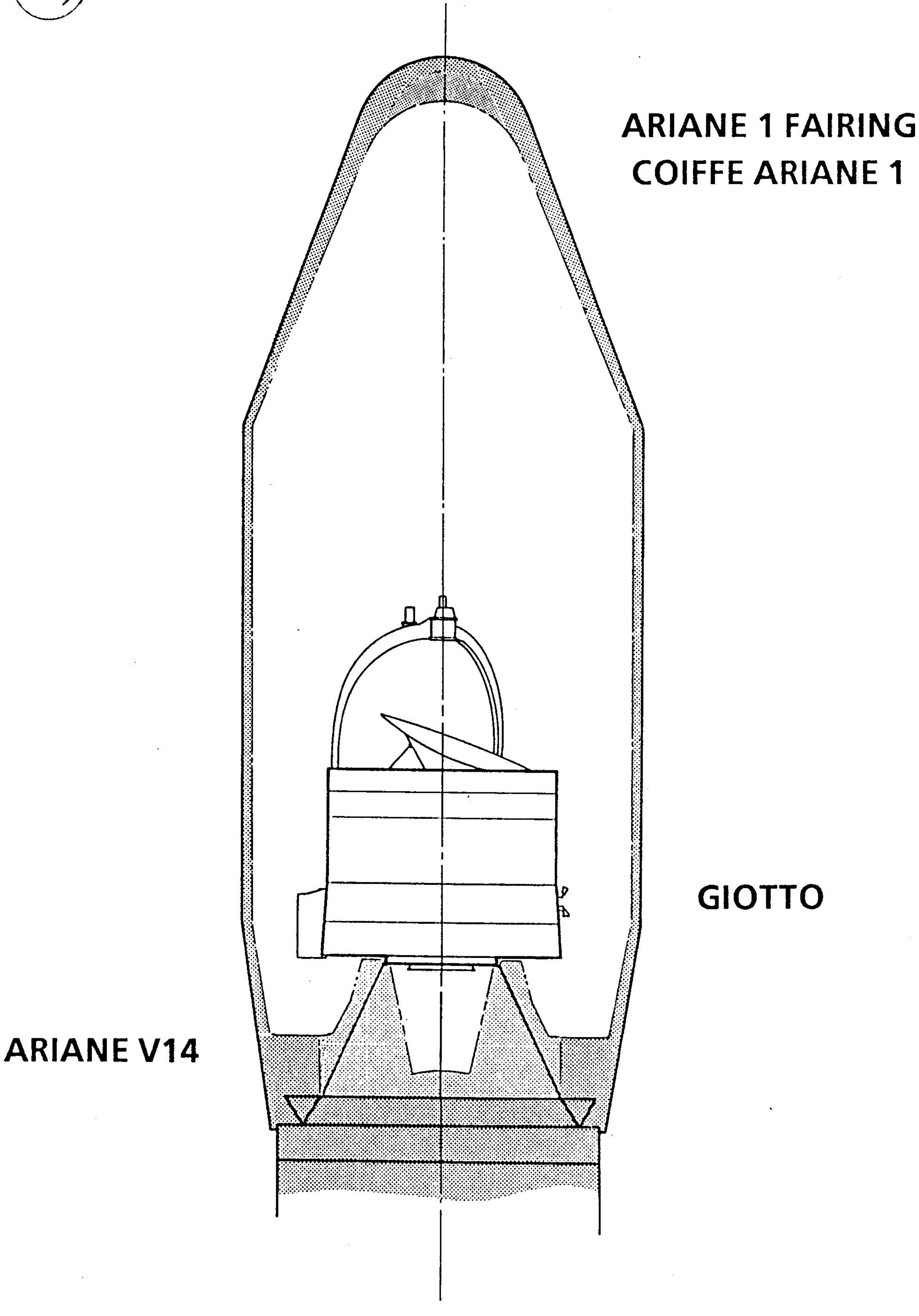
3. ARIANE V14 - GIOTTO

4. Launch count-down

5. Lift-off and flight sequence

6. Informations on the trajectory

7. Launch-base mission requirements summary



Présentation du satellite GIOTTO sous la coiffe ARIANE 1
ARIANE 1 fairing with the GIOTTO spacecraft

1. Purpose of the flight "ARIANE V14 GIOTTO"

The 14th Ariane Launch (V14) is scheduled to place the GIOTTO spacecraft (960 kg) into a geostationary transfer orbit (GTO) before its escape mission aiming at encountering the Comet Halley at its next apparition in March 1986. An ARIANE 1 launch vehicle is dedicated to the GIOTTO launch.

Secondary mission : In order to try to recover the Ariane first stage at the time of its splashdown on the sea, the interstage 1/2 has been equipped with parachutes to be deployed by on-board sequencer, 373 seconds after first stage separation.
The main purpose of this experiment is to demonstrate the technical feasibility and to evaluate the financial savings of the recovery.

Required GTO characteristics are :

Perigee altitude : 200 km

Apogee altitude : 35 966 km for GIOTTO

35 897 km for the ARIANE 3rd stage at injection

Inclination : 7 degrees

The count-down sequence is organized to obtain lift-off of the Ariane 1 launcher used for V14 from the first ARIANE launch site (ELA-1)

Between 11:13 a.m. and 00:17 p.m. Universal Time (GMT)

namely 08:13 a.m. to 09:17 a.m. Kourou Time

or from 07:13 a.m. to 08:17 a.m. EDT

or from 01:13 p.m. to 02:17 p.m. Paris Time

WITH NOMINAL LAUNCH DATE ON TUESDAY, JULY 2, 1985 (Kourou time)

2. V14 Key Personnel
Principaux responsables pour le vol 14

Chef de Mission Mission Director	Y. GUERIN	ARIANESPACE
Responsable Charge Utile ARIANE (RCUA) et Mission Manager de GIOTTO ARIANE Payload Manager and GIOTTO Mission Manager	B. GUILLAUMANT	ARIANESPACE
Chef de Projet ARIANE Production (CPAP) ARIANE Production Project Manager	G. LE GUERN	ARIANESPACE
Chef de Projet Récupération 1er étage First stage recovery Project Manager	A. VAN GAVER	CNES/DLA
Directeur de Mission Satellite (DMS) Spacecraft Mission Director	M. DELAHAIS	ESA/ESTEC
Chef de Projet Satellite (CPS) Spacecraft Project Manager	D. DALE	ESA/ESTEC
Responsable Préparation Satellite (RPS) Spacecraft Preparation Manager	J. CREDLAND	BAE
Responsable Interface Satellite/Lanceur ARIANE/Spacecraft Interface Manager	P. LOGALBO	ESTEC
Chef des Opérations Ensemble de lancement (COEL) Launch Site Operations Manager	J.M. AGASSE	ARIANESPACE
Assistant Charge Utile (ACU) Payload Interface Operations Officer	P. SEGESSEMAN	ARIANESPACE
Directeur Délégué des Opérations Range Operations Deputy Manager	M. RABE	CNES/CSG
Responsable Moyens Charge Utile (RMCU) RMCU Manager	M. LAMBELIN	CNES/CSG
Ingénieur Sauvegarde Charge Utile (ISCU) Payload Safety Officer	R. LOUPEC	CNES/CSG
Responsable Sauvegarde Vol Flight Safety Officer	H.BACCINI	CNES/CSG

3. ARIANE V 14 - GIOTTO launch operations

The GIOTTO launch operation programme lasts 10 weeks from arrival at Cayenne of the spacecraft until launch.

The ARIANE 1 launch operation programme lasts 28 working days.

DATES		ARIANE ACTIVITIES	SPACECRAFT ACTIVITIES
	Mo 29/04/85		**GIOTTO arrival at Kourou**
J - 27	Tu 28/05	1st stage inspection	)
J - 26	We 29/05	1st stage erection	)
J - 25	Th 30/05	2nd stage erection	) Spacecraft preparation (S1 Building)
J - 21	Tu 04/06	3rd stage erection	)
J - 20	We 05/06	VEB mating	)
J - 19	Th 06/06	)	GIOTTO moved into S3 for
J - 10	We 19/06	Overall test)	tanks filling and pressurization
J - 8	Fr 21/06	3rd stage filling rehearsal)	and kick motor integration
J - 7	Mo 24/06	Guidance platform calibration	GIOTTO mated on adaptor and secured into CCU
J - 6	Tu 25/06	**CCU transport on tower and GIOTTO mated on Ariane-Spacecraft checks**	
J - 5	We 26/06	Fairing assembly	Spacecraft checks
J - 4	Th 27/06	**ARIANE, ELA, CSG AND SPACECRAFT FINAL PREPARATION AND LAUNCH REHEARSAL (during the night)**	
J - 3	Fr 28/06	**FAIRING FINAL CLAMPBAND TENSIONING**	
J - 2	Sa 29/06	**LAUNCH READINESS REVIEW AND ARIANE ARMING**	
J - 2 bis	Su 30/06	**GIOTTO ARMING**	
J - 1	Mo 01/07	**LAUNCH COUNTDOWN**	
Jo	Tu 02/07	**LAUNCH COUNTDOWN**	

4. Launch count-down

All operations connected with final preparation of the launcher and the payload, leading to a configuration authorizing ignition of the Ariane motors at the launch time selected Ho, are grouped under the designation of count-down.

Count-down terminates with a synchronized sequence, controlled by the Ariane ground check-out computers, starting at Ho - 6 minutes.

Count-down

Count-down is divided into two phases ; day preceding launch and launch day ;

- the first phase concerns all storable propellants filling operations (UDMH and $N^2 0^4$) for the first and second stages.

  This phase lasts about 17 hours and ends about 11 hours before the launch. Usually a "HOLD" of several hours is programmed at this step.

- the second phase, starts at Ho - 11 h 15 and ends by the 6 minutes "Synchronized sequence" leading to lift off.

Synchronized sequence

The synchronized sequence starts at Ho - 6 mn. This sequence is used for final preparation of the launcher, and check-out operations made necessary by the switch-over to flight configuration. The sequence is fully automatic, and is controlled in parallel, up to Ho - 4 seconds, by two computers in the Ariane Launch Center. All resources used for launch are synchronized on a common count-down sequence.

One computer carries out flight configuration of the fluids and propellants and the associated checks. The other computer executes final preparation of the electrical systems (initiation of flight program, start-up of servomotors, switch-over from ground power supplies to flight batteries, etc.) and corresponding check-out operations.

From Ho - 4s, a majority logic sequencer - the Automatic release phase system - delivers the main timing pulses for :

- retraction of the cryogenic arms (Ho-4s)
- first stage motors ignition (Ho)
- motor parameters check-out (conducted in parallel by the two computers, from Ho + 2.8s)
- opening of the launch table hooks (releasing the launch vehicle between Ho + 3s and Ho + 4s), as soon as motor parameters are found nominal by one of the computers.

Any stoppage of the synchronized sequence before Ho - 4s resets the launcher automatically to initial configuration (Ho - 6mn). However, the count-down is restarted at Ho - 8mn to allow for payload flight configuration check-out routines.

Main phases of the countdown sequence

Date	KOUROU Time	Countdown Time	Events
			Countdown sequence : 1st part
JUNE 30,85	09:00 p.m.	**Ho - 29h 00**	Placing in configuration all ground systems
JULY 1, 85	00:00 a.m.	Ho - 26h 00 to Ho - 21h 40	1st and 2nd stage N204 filling
		Ho - 18h 55 to Ho - 14h 20	1st and 2nd stage UDMH filling.
		Ho - 14h 20 to Ho - 12h 15	1st and 2nd stage propulsion system cheks
	01:45 p.m.		**Count down hold**
			Countdown sequence : 2nd part
	08:43 p.m.	**Ho - 11h 30**	Ho display
		Ho - 11h 15 to Ho - 6h	Preparation of launcher and tower for tower withdrawal
	09:58 p.m.	Ho - 10h 15 to Ho - 7h 15	GIOTTO functional tests
JULY 2, 85	02:13 a.m.	Ho - 6h 00 to Ho - 5h 15	Tower withdrawal
		Ho - 6h 00 to Ho - 4h 35	Alignment of inertial guidance platform
		Ho - 5h 50	Start of third stage tank flushing
		Ho - 5h 15 to Ho - 4h 50	Launcher telemetry transmission test for CSG stations
		Ho - 4h 50 to Ho - 3h 20	Second stage helium spheres pressurization
		Ho - 4h 55 to Ho - 3h 35	Third stage filling preparation
	04:38 a.m.	Ho - 3h 35	Start of third stage filling (liquid oxygen and hydrogen)
		Ho - 2h 40 to Ho - 1h 40	Flight pressurization of 1st and 2nd stage tanks
		Ho - 2h 05 to Ho - 1h 05	ARIANE functional checks
	07:08 a.m.	Ho - 1h 05	Second stage helium tank final pressurization. Third stage propellants topping. Activation of launcher telemetry, radar transponders, telecommand
	07:18 a.m.	Ho - 55 mn	SPACECRAFT motor arming
	07:23 a.m.	Ho - 50 mn	Flight program loading.
	08:05 a.m.	Ho - 8 mn	"Green" status for all systems. SPACECRAFT switched to on-board batteries
		Ho - 6 mn	Initiation of synchronized launch sequence
		Ho - 1 mn	Launcher equipment switched to on-board batteries
		Ho - 9 s	Inertial platform released
		Ho - 4 s	Release command to cryogenic arms retraction system
JULY 2, 85	08:13 a.m.	**Ho**	**First stage ignition**
		Ho + 3,4 s	Lift-off
		Ho + 8 s	End of synchronized launch sequence and reset to initial configuration

5. Lift-off and flight sequence

Countdown time (related to H0)		Events
- 9 s		Inertial platform released
- 4 s		Release command to cryogenic arms retraction system
- 0.2 s		Cryogenic arms withdrawal report
0 **(H0)**		**First stage ignition**
+ 3.4 s		**Lift-off**
+ 13 s		End of vertical ascent phase and start of roll motion
+ 23.0 s		Pitch motion in a constant azimuth plane of 70°. Atmospheric flight at zero angle of attach in pitch
+ 72.0 s	1mn 12.0s	Transsonic
+ 82.0 s	1mn 22.0s	Maximum of dynamic pressure
+ 145.5s **(H1)**	2mn 25.0s	First stage half-thrust detection (first stage burn-out)
+ 147.4s	2mn 27.4s	Second stage acceleration rockets ignition
+ 149.9s	2mn 29.9s	**Stage 1/2 separation.** First stage retro rockets ignition
+ 151.8s	2mn 31.8s	**Second stage ignition**
+ 154.0s	2mn 34.0s	Second stage nominal thrust
+ 157.4s	2mn 37.4s	Second stage acceleration rockets jettisoning
+ 160.0s	2mn 40.0s	Start of guidance phase. Yaw manoeuvre
+ 254.0s	4mn 14.0s	**Fairing jettisoning**
+ 285.4s **(H2)**	4mn 45.4s	Activation of second stage cut-off sequence
+ 286.2s	4mn 46.2s	Third stage acceleration rockets ignition
+ 290.4s	4mn 50.4s	**Stage 2/3 separation.** Second stage retro rockets ignition
+ 293.7s	4mn 53.7s	**Third stage ignition**
+ 295.4s	4mn 55.4s	Third stage nominal thrust
+ 306.2s	5mn 06.2s	Third stage acceleration rockets jettisoning

+	360 s		7 mn	Launcher acquired by Natal ground station (tracking until 14 mn)
+	520 s		8 mn 40 s	Trajectory culmination (392 km)
+	790 s		13 mn 10 s	Launcher acquired by Ascension Island station (tracking until 18 mn 30 s)
+	850.8 s	**(H3)**	14 mn 10.8 s	Activitation of third stage shutdown sequence
+	852.2 s		14 mn 12.2 s	**Injection velocity achieved** (end of third stage propulsion shutdown phase)
+	852.8 s		14 mn 12.8 s	Start of 3rd stage orientation by the Roll and Attitude Control System (SCAR) for GIOTTO alignment
+	881.1 s		14 mn 41.1 s	Spin-up (10 rpm)
+	899.2 s	**(H4)**	14 mn 59.2 s	**GIOTTO separation**
+	903.2 s		15 mn 03.2 s	ARIANE avoidance sequence (spin-down, re-orientation, spin-up to 10 rpm)
+	1 249.0 s	**(H5)**	20 mn 49.0 s	End of ARIANE flight mission

Note : Nominal Ignition of the GIOTTO kick motor is scheduled at 4th Perigee passage.

6. Informations on the trajectory

The launcher ascends vertically from Ho + 3.4 s to Ho + 13s. After a roll motion, it tilts at Ho + 23s, in the pitch plane defined by the launch azimuth (70°) and the inertial vertical passing through the table at the instant of unlocking the inertial platform 9 s before first stage motors ignition (Ho-9s).

The vehicle's attitude is commanded by a predetermined law which nominally provides a zero-incidence trajectory in that constant azimuth plane of 70°. The guidance phase initiated 10s after ignition of the 2nd stage rotates the trajectory plane of about 24°, with the rate of 2 degrees per second. The attitude law in the pitch and yaw plane is optimised in order to minimize the 3rd stage propulsion time necessary to reach the geostationary transfer orbit with a performance margin of about 230 kg enabling more than 99,86 % of mission success.

The roll law is applied so as to improve the launcher / ground stations radio link budget. On request of the GIOTTO program authority, the launcher is slowly spun (at 2 degrees/sec.) after about 500 seconds, until injection.

In the following pages are presented :

- ARIANE V 14 Orientation on its launch pad
- Main characteristics of the V 14 nominal trajectory
- V 14 Flight profile
- V 14 Ground stations visibility

  . In Guiana : Kourou (Montagne des Pères) and Cayenne (Montabo),
  . In Brazil : Natal,
  . Ascension Island

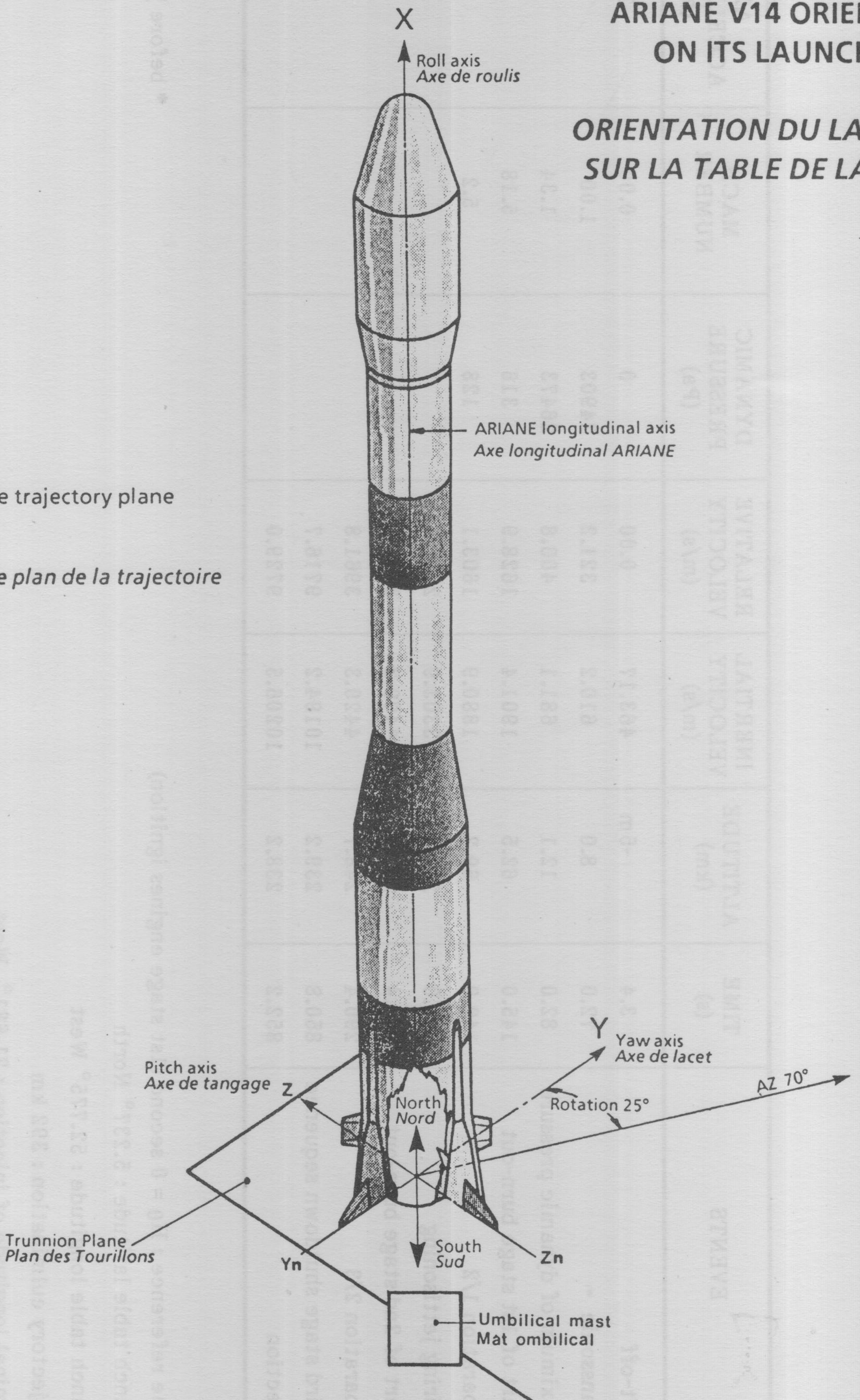
- V 14 In-flight mass profile

ARIANE V14 ORIENTATION ON ITS LAUNCH PAD

ORIENTATION DU LANCEUR V14 SUR LA TABLE DE LANCEMENT

XY is the trajectory plane

XY est le plan de la trajectoire



MAIN CHARACTERISTICS OF THE NOMINAL TRAJECTORY V14

EVENTS	TIME (s)	ALTITUDE (km)	INERTIAL VELOCITY (m/s)	RELATIVE VELOCITY (m/s)	DYNAMIC PRESSURE (Pa)	MACH NUMBER	AXIAL ACCELERATION (m/s^2)
Lift-off	3.4	-5m	463.17	0.00	0	0.00	11.82
Transsonic	72.0	8.0	610.2	321.2	24903	1.00	17.1
Maximum of dynamic pressure	82.0	12.1	681.1	400.8	26473	1.34	18.4
Start of 1st stage burn-out	145.0	62.5	1901.4	1628.9	316	5.18	41.3
Separation 1/2	149.9	69.2	1880.9	1603.1	128	5.2	0.4
Fairing jettisoning	254.0	204.8	3303.9	2864.6			30.4*
Start of 2nd stage burn-out	285.4	242.7	4400.2	3943.2			47.9
Separation 2/3	290.4	248.7	4420.3	3961.8			0.8
Third stage shutdown sequence	850.8	239.2	10194.2	9716.7			22.8
Injection	852.2	238.2	10206.5	9729.0			0.01

* before jettisoning

Time reference : H_0 = 0 second (1st stage engines ignition)

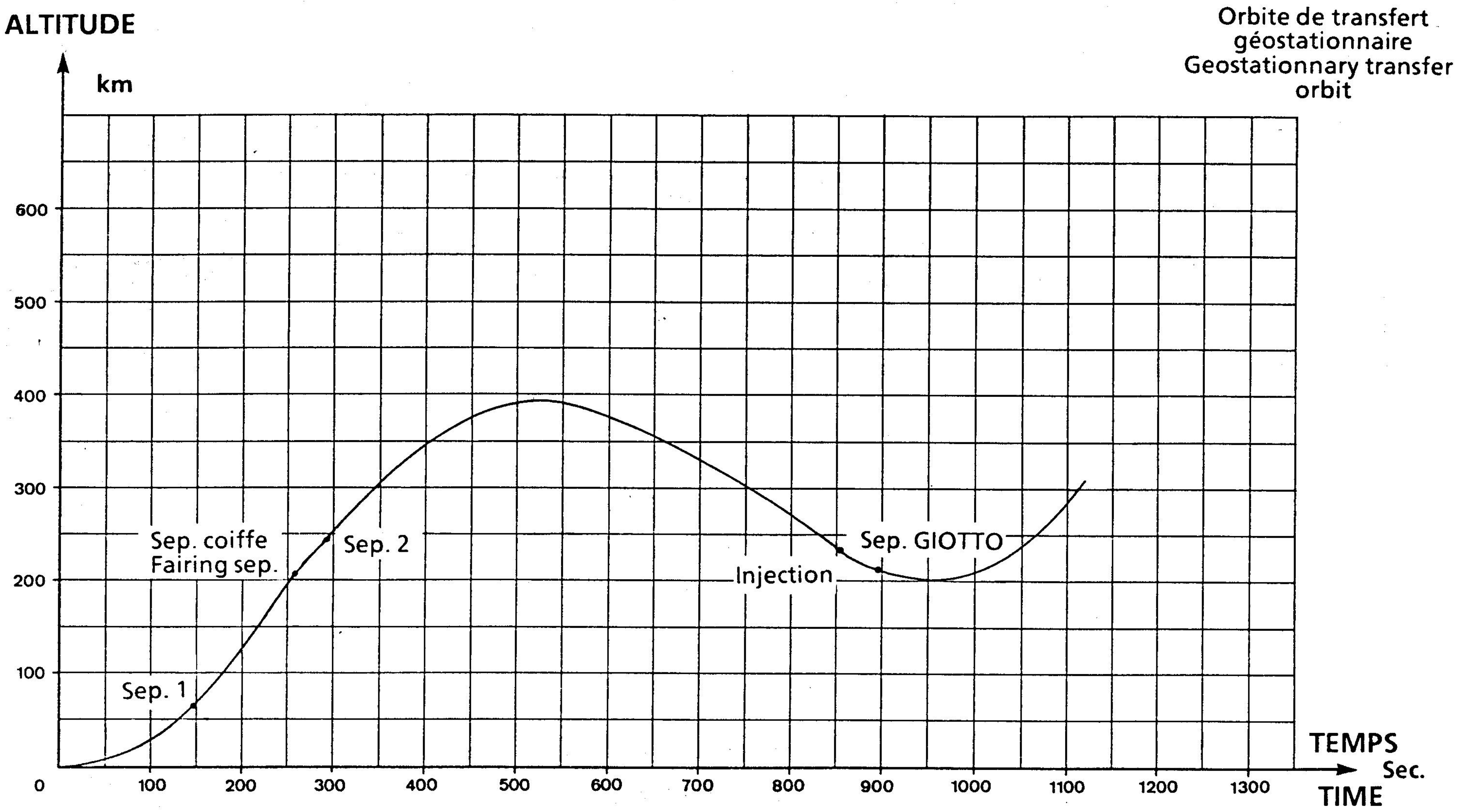
Launch table latitude : 5.237° North

Launch table longitude : 52.775° West

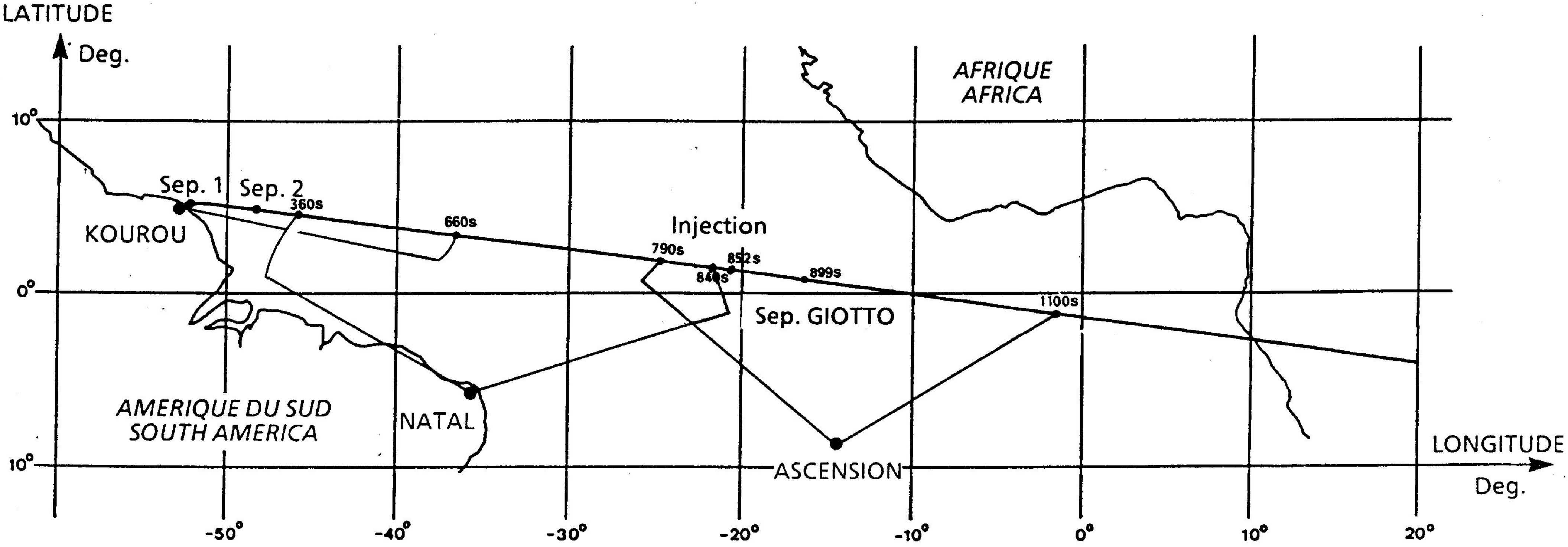
Trajectory culmination : 392 km

Nominal longitude of injection : 21.681° West

Trajectoire
ARIANE V14 - GIOTTO
Flight profile



Visibilité des stations sol (site = 1°)
ARIANE V14 - GIOTTO
Ground stations visibility (Elevation = 1°)



V14 In-flight launcher mass profile

The mass of the ARIANE 1 launcher, including the GIOTTO spacecraft, at first stage motors ignition (Ho) and lift-off is 209815 kg and 208304 kg respectively.

Constitutive elements	Mass (kg)	
GIOTTO		**960**
Spacecraft adapter	40	
3rd stage vehicle (H8) dry mass	1115	
Vehicle Equipment Bay (VEB)	272	
Residual fluids	59	
Performance reserve	230	
	1716	
ARIANE mass after end of 3rd stage propulsion		**2676**
HM7 thrust decay propellants	8	
H8 non-propulsive fluids (ejected)	3	
Propellants usable in H8 steady state phase	7857	
H8 thrust build-up propellants	18	
	7886	
ARIANE mass after 2nd stage separation		**10562**
Interstage 2/3	464	
2nd stage (L33) dry mass	3109	
L33 residual fluids	772	
L33 thrust decay propellants	215	
Non-propulsive fluids (ejected from L33 and H8)	75	
Propellants usable in L33 steady state phase	33021	
Jettisoned fairing	842	
L33 thrust build-up propellants	202	
	38700	
ARIANE mass after 1st-stage separation		**49262**
Interstage 1/2	681	
1st stage (L140) dry mass	14220	
L140 residual fluids	1161	
L140 thrust decay propellants	1065	
Non-propulsive fuels (ejected from L140 and H8)	57	
Propellants useful in steady state phase	141858	
	159042	
ARIANE mass at lift-off		**208304**
Propellants for ignition phase	**1511**	
ARIANE and spacecraft mass at Ho (1st stage ignition)		**209815**

7. Launch-Base mission requirements summary

Acquisition of on-board telemetry

Launch Base ground telemetry stations configuration must provide for :

- continuous acquisition of all data (about 600 parameters) transmitted by the Vehicle Equipment Bay telemetry (telemetry FM/PCM, in E band, 15 W), from the final launcher preparation stage up to the end of the third stage flight mission.
- continuous acquisition of first stage data until its splashdown on the ocean
- recording on magnetic tape of all telemetry data received
- events dating
- telemetry data retrieval

Tracking of the launcher

The configuration of the Launch Base ground facilities must provide for the following, using external measurement equipment :

- Real time launcher location and display of the trajectory
  - . mandatorily
  - . so far as possible
- provisional diagnosis of orbit injection not later than 30 minutes after separation of the satellite, with accuracy as follows :

apogee :	± 500km
perigee :	± 5km

- off-line retrieval
  - . launcher verticality deviation at lift-off
  - . launcher position and attitude with respect to the umbilical mast up to the moment of clearing the mast.
  - . trajectory azimuth for the first 80 seconds of flight
  - . launcher position and velocity during the flight

Event retrieval

Retrieval and dating of the following events by optical equipment must be possible :

- lift-off phase

. first stage ignition
. opening of release jaws and disengagement from the launch table
. jettisoning of umbilicals

- flight phase

. first stage propulsion phase
. stage 1/2 separation
. fairing jettisoning

Safety requirements

An Ariane launch must not entail a risk factor exceeding 10^{-7}(1/10.000.000) with respect to persons or property, during the safety mission.

Application of this risk level criterion, as adopted for launch operations, requires the use of facilities and application of procedures

The Safety Officer must be kept informed of the trajectory and the launcher status at all times, from lift-off up to the end of the safety mission.

The status data concern :

- the progress of the launcher inside an authorized volume, requiring adequate visibility during the initial flight phase ; this data is provided by telelimiters for the vertical ascent phase and later by the radars.

- the instantaneous impact point position

Throughout the safety mission, the Safety officer is supplied with telemetry data from the launcher, concerning the status of the on-board destruct system, indicating launcher attitude and propulsion characteristics.

The Safety Officer must be in a position to order destruction of the launcher if its trajectory deviates, or can deviate dangerously.

Fall-back of the stages onto the ground or into the sea must not incur hazards for persons or property, exceeding authorized risks.

On impact, the stages must not constitute obstacles to navigation, nor contain any hazardous products.

If evacuation of the land areas concerned has not been completed, the launch is postponed.

Launch environment

The weather conditions for the tower withdrawal depend of the stages pressurization values. The wind speed has to be below 15 m/s.
The wind speed limits at lift-off are between 9 m/s and 14 m/s according to the wind direction, the most restraining condition being a North wind.

At lift off, the following conditions must be met :

- Horizontal visibility better than 600 m
- Altitude of the clouds higher than 250 m

Meteorological facilities must provide for :

- evaluation of lighthing risks in the vicinity of the launch site after withdrawal of the tower, and during the first part of launcher flight

- the forecasts required for the hazardous operations (wind, rain, etc...) on the range

- mean wind profile, pressure and temperature data up to an altitude of 30 km, obtained from radio-sonde balloon. These parameters must be measured within the hour following the launch.

CHAPTER 2

THE ARIANE LAUNCH VEHICLES

1. Programme Highlights

2. Ariane 1 Programme

3. Ariane 2 and 3 Programme

4. General description of the Ariane 1 launch vehicle

5. The Ariane 4 programme

6. Ariane 5

1. Programme highlights

31 July 1973 :	The Ministers responsible for space matters in ten European countries, decided, at the European Space Conference, that it was essentiel for Europe to have a competitive launcher if it wished to ensure its independence and enter the international market for applications satellites.
28 December 1973 :	Coming into force of the Agreement between participating states and ESRO (which has since become ESA) on the development of the Ariane launcher.

The Member States' participation in the ARIANE 1 development programme was :

. Germany	20.12 %
. Belgium	5.00 %
. Denmark	0.50 %
. Spain	2.00 %
. France	63.87 %
. Netherlands	2.00 %
. Italy	1.74 %
. United Kingdom	2.47 %
. Sweden	1.10 %
. Switzerland	1.20 %

ESA was entrusted with the monitoring of the execution of the programme. The technical experience on which the design of the Ariane launcher is based and the technical consistency required led to the selection of CNES as prime contractor.

For the development phase, CNES placed six direct first-level contracts with European firms :

- AEROSPATIALE-DSBS, as industrial architect,
- AEROSPATIALE (Centre Technique des Mureaux) as stage authority,
- SEP, for the development of the propulsion systems of the three stages,
- Air Liquide, for developing the cryogenic structures of the 3rd stage,
- MATRA, for developing the vehicle equipment bay,
- The Belgian firm of ETCA for the checkout system.

April 1978 : ESA decision to start production of a "promotion series" of 6 operational launchers.
The promotion series also included the construction of the payload facilities (EPCU = Ensemble de Préparation des Charges Utiles) and the development of a device for launching two satellites simultaneously, known as "SYLDA" (Système de Lancement Double Ariane). The promotion series was executed by the participants in the development phase, together with Ireland which entered the programme for the production phase. ERNO became first level contractor for the second stage.

24 December 1979 : Ariane 1 first test flight (L01) : a success.

23 May 1980 : Second Ariane 1 test flight (L02) : a failure due to a malfunction of one of the first stage engines ; the two satellites on-board Firewheel and Oscar-9 - were lost.

3 July 1980 : ESA decision to undertake an Ariane follow-on development programme for the development of two more powerful versions of the launcher, **Ariane 2 and Ariane 3.**

19 June 1981 : Third Ariane 1 test flight (L03), successfully launched an ESA spacecraft, Meteosat-2 and an Indian Communications Satellite, APPLE.

31 July 1981 : Decision to start the construction of a **second launch site (ELA-2)** at Kourou came into force. 7 ESA Member States (Germany, Belgium, Denmark, Spain, France, Italy, Switzerland) participate in this programme. ELA-2 is expected to be operational mid 1985.

20 December 1981 : Last Ariane 1 test flight (L04), successfully launched the first Maritime European Communications Satellite, MARECS-A (ESA).

13 January 1982 : ESA decision to develop **Ariane 4**, an improved version of the launcher. The first launch of Ariane 4 is scheduled for mid-1986.

9 September 1982 : First flight of the promotion series (L5) : a failure due to a malfunction in the turbopump of the third stage engine. The payload, consisting of two ESA spacecraft, MARECS-B and SIRIO - 2, was lost.

16 June 1983 : Ariane L6 successfully launched the first European Communications Satellite ECS-1 (ESA) and the radioamateur AMSAT Phase 3-B satellite.

19 October 1983 : Ariane L7 successfully launched INTELSAT V F7.

4 March 1984 : 8th flight of Ariane (identified by the serial number of the flight "V" (in French : Vol) and not, as previously by that of the Launcher "L") successfully launched INTELSAT V F8.

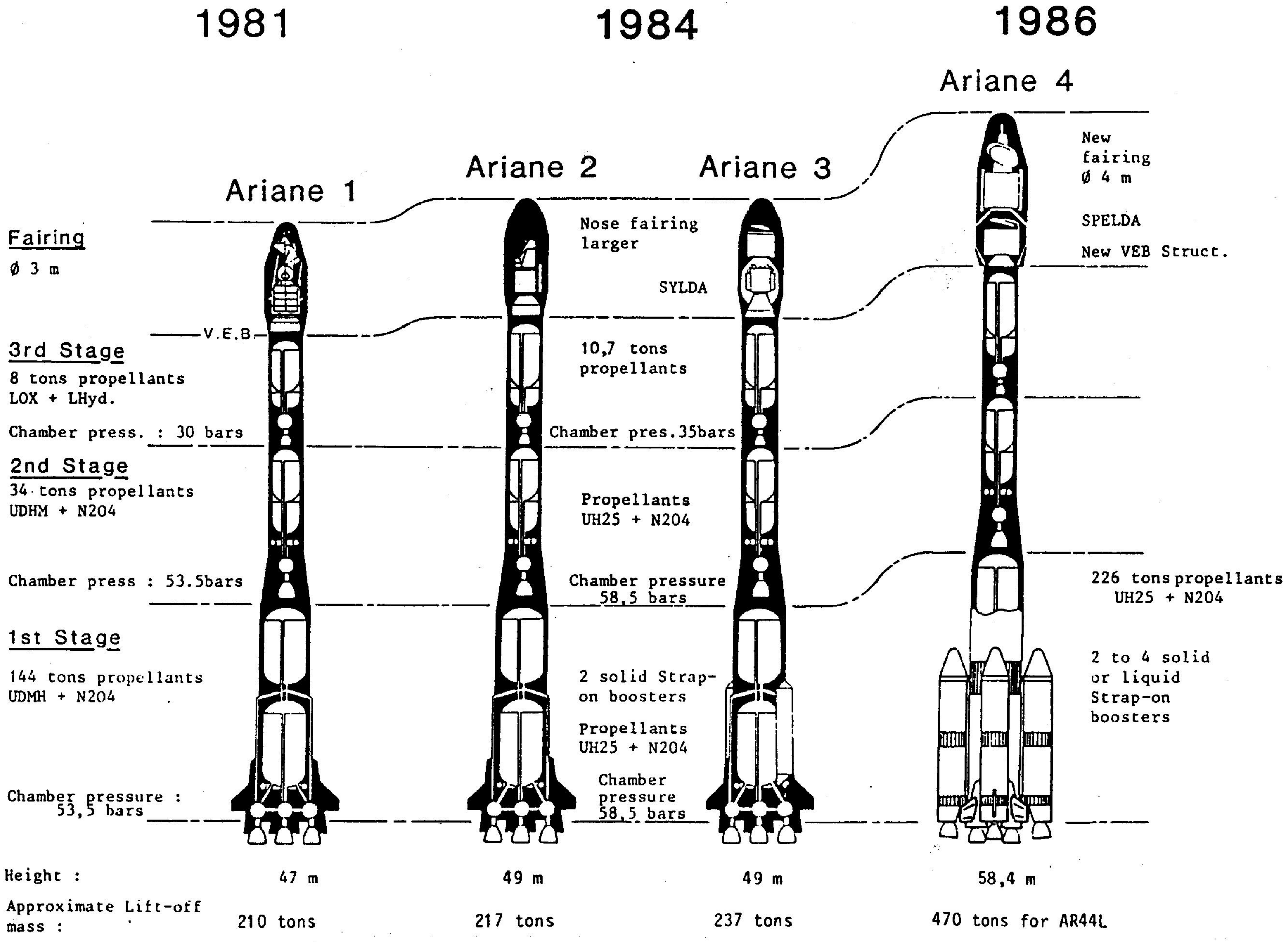
22 May 1984 : First commercial launch (Ariane V9) carried out by Arianespace, successfully injected GTE's Spacenet-F1 into orbit.

4 August 1984 : Ariane V10 (first Ariane 3 flight) carried out by Arianespace successfully launched the second European Communications Satellite ECS-2 and the French Telecom 1A Satellite.

10 November 1984 : Ariane V11 (Ariane 3 ELV type) carried out by Arianespace, successfully launched the second GTE's Spacenet 2 Satellite and the Maritime European Communications Satellite Marecs B2.

8 February 1985 : Ariane V12 (Ariane 3 ELV type) carried out by Arianespace, successfully launched ARABSAT F1 and BRASILSAT 1.

8 May 1985 : Ariane V13 (Ariane 3 ELV type) carried out by Arianespace, successfully launched the American GSTAR 1 satellite and the French Telecom 1B satellite.


1981
1984
1986
Ariane 1
Ariane 2
Ariane 3
Ariane 4
Fairing
Ø 3 m
V.E.B.
3rd Stage
8 tons propellants
LOX + LHyd.
Chamber press. : 30 bars
2nd Stage
34 tons propellants
UDHM + N2O4
Chamber press : 53.5bars
1st Stage
144 tons propellants
UDMH + N2O4
Chamber pressure : 53,5 bars
Height :
Approximate Lift-off mass :
47 m
210 tons
Nose fairing larger
SYLDA
10,7 tons propellants
Chamber pres.35bars
Propellants UH25 + N2O4
Chamber pressure 58,5 bars
2 solid Strap-on boosters
Propellants UH25 + N2O4
Chamber pressure 58,5 bars
49 m
217 tons
49 m
237 tons
New fairing Ø 4 m
SPELDA
New VEB Struct.
226 tons propellants UH25 + N2O4
2 to 4 solid or liquid Strap-on boosters
58,4 m
470 tons for AR44L

2. The Ariane 1 programme

Historical background

As far back as 1970, the spectacular progress of space applications brought home to Europe the political an economic importance of utilising space. Everything pointed to the establishment of space systems for commercial purposes in the 1980s : telecommunications, direct television, meteorology, Earth observation, etc. In 1973, various surveys estimated that, during the same decade, 180 satellites would be placed in geosynchronous orbit, including 23 for Europe. These forecasts are now amply confirmed.

If Europe wished to ensure its independence of the nations that possess launch facilities and to enter the international market for applications satellites, it was essential for it to have a competitive launcher. Such was the tenor of the decision taken at Brussels on 31 July 1973 by the Ministers responsible for space matters in ten European countries, meeting in the European Space Conference.

Framework for execution of the programme

The agreement reached in Brussels was given concrete form by an "Arrangement" between the participating States and ESRO, which has since become the European Space Agency (ESA).

The development of the Ariane launcher is one of ESA's optional programmes. Its aim is to provide Europe with its own launch system for carrying out its space programme.

Early in the 1970s, ESA had already embarked on applications-satellite programmes in telecommunications and Earth-observation, for which such an independent launch capability was clearly essential.

The ESA applications satellites and those derived from them in order to meet Member States' requirements will therefore be Ariane's first guaranteed customers. Likewise, in drawing up the scientific-satellite programme, account will henceforth be taken of the new European launch capabilities.

the precise financial commitments of each participating Member State were laid down from the start. The cost of the development programme was fixed at 379.89 MAU (FF 2060 million) at January 1973 economic conditions, and the participating States undertook to cover any technical contingencies up to 20 % of this sum. In addition, France guarantees to finance alone any further overrun up to 15 % of the nominal cost of the programme.

A programme Board, composed of representatives of the participating States, is responsible for the programme and takes all relevant decisions.

The Arrangement, which came into force on 28 December 1973, provided a sound basis for managing this complex international programme.

3. The ARIANE 2 and 3 programme

Legal and financial basis of the development programme

The discussions on a complementary development started in December 1978 when the ESA Executive submitted a proposal to its Council to increase the Ariane launcher performance. At that time it had become clear that the mass of the Atlas Centaur class satellites would increase and that an uprated Ariane launcher (using the dual launch payload adapter "Sylda") could launch simultaneously two Delta class satellites. In addition, due to the scale effect, a higher performing launcher promised to yield lower specific launch costs (cost per kg in orbit).

The carrying out of a "Preparatory Phase" in view of a complementary development programme was decided on 26 July 1979 (France, Germany and Italy).
The decision to implement this development programme was finally taken on 3 July 1980. Almost all ESA Member States participated in the Ariane 2/3 development programme (which was split into 4 "slices").

The contribution scale to the financial envelope of the main slice initially estimated at about 70 MAU (mid-1979 prices) is as follows :

Germany	17.28 %	Italy	16.29 %
Belgium	0.84 %	Netherlands	0.25 %
Spain	0.84 %	Sweden	2.09 %
France	62.41 %		

The second slice estimated at about 9 MAU (mid 1979 prices) covers the modification of the Ariane fairing and -being a long lead item- the development of the Ariane 4 fairing. This work is 95.44 % financed by Switzerland and 4.56 % by France. The 3rd and 4th slices, of a total value of not more than 4 MAU (mid 1979 prices), are financed by several participating Member States including Denmark.

The United Kingdom participates through a bilateral agreement with France.

A contingency margin of up to 20 % of the nominal programme cost was provided for by the Participants (as is usual for ESA development programmes). This margin was in fact used up in the course of the programme execution.

The Ariane Programme Board, composed of representatives of the participating Member States is responsible for this programme and takes all relevant decisions.
As was the case with the Ariane 1 development programme, the execution of the Ariane 2/3 development programme was entrusted to CNES, with ESA in charge of monitoring the execution of the programme.

ARIANE 2 and 3 programme objective and content

The main objective of the Ariane 2/3 development programme was to increase the Ariane launch capability into the geosynchronous transfer orbit up to 2580 kg (including the payload adaptor mass) for a single launch or two times 1195 kg (separated spacecraft mass) for a dual launch.

The programme also included the construction of a new telemetry ground station (necessary due to the longer flight time, the final phase of the launch vehicle flight being no longer invisibility from Ascension Island) and the necessary adaptation of the launch pad facilities and checkout station. The nature of the envisaged modifications did however not require a particular in-flight demonstration. Thus the programme was limited to the qualification on ground of the modifications and new elements.

ARIANE 2 and 3 ground qualification

The major modifications with respect to the Ariane 1 vehicle are the following :

a) Biconic forward section of the fairing,

b) Lengthening (500 mm) of the cylindrical section of Sylda,

c) Third stage tanks stretched by 1.3 m ; propellant mass increased from 8 to 10.7 t,

d) Third stage engine nozzle throat decreased ; expansion nozzle lengthened by 20 cm ; chamber pressure increased from 30 to 35 bar ; expansion ratio increased from 60 to 83 ; specific impulse gain of about 4s,

e) Third stage thrust phase maximum duration increased from 570s to 735s,

f) Second stage Viking engine chamber pressure increase from 53.5 to 58.5 bar ; thrust increase of 9 %,

g) Modification of the first stage intertank skirt for the attachment of the forward end of the strap-on boosters,

h) Modification and reinforcement of the first stage thrust frame for the attachment of the aft end and thrust introduction of the strap-on boosters,

i) Addition to the 1st stage of 2 strap-on boosters, each containing 7.3 tonnes of solid propellant and capable of 70 tonnes of thrust,

j) First stage Viking engines chamber pressure increase from 53.5 to 58.5 bar ; thrust increase of 9 %,

k) Use of a mixture (UH25) made of 75 % UDMH and 25 % Hydrazine hydrate, instead of UDMH.

The only really new element is the 7.3 t. solid propellant strap-on booster together with its attachment and separation system.
A part from studies, this item has essentially been qualified by appropriate testing, in particular by 4 full-scale development firing tests and 4 successful qualification firings. The separation mechanism has been qualified by a series of full-scale separation tests.

All these modifications have been qualified by analysis and appropriate testing. Special care has been given for example to the consequences of the longer third stage thrust duration on the third stage functioning, and to the availability of a sufficient combustion stability margin for the Viking engines in view of the chamber pressure increase.

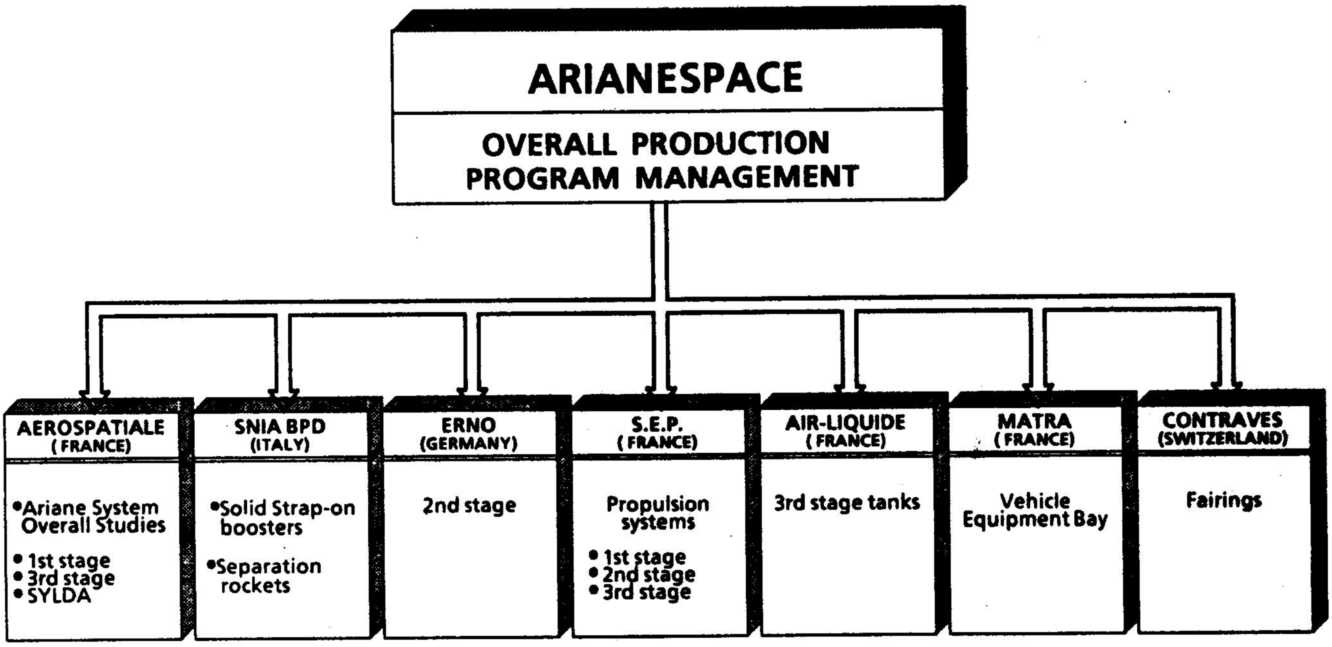
The overall integrity of the vehicle and compatibility of the modifications have been verified by extensive system analysis studies (trajectory and performance, flight mechanics/separations, aerodynamics, thermal, acoustic, general loads, POGO, guidance and control) based on, or completed by, system level tests such as aerodynamic tests, thermal and acoustic tests, vibration mode searches, guidance and control simulations.

All necessary design and qualification reviews have been carried out by CNES, together with the industrial firms concerned, on the modified items and at system level.
In addition, ESA and CNES have established a Launcher Qualification Committee which, since September 1983, has thoroughly examined the qualification status of the vehicle and its elements. This Committee has submitted a report to the Directors General of ESA and CNES concluding that the new vehicle can be considered as qualified and flightworthy.
Arianespace, responsible for the operational use of the Ariane vehicles, was represented on the Launcher Qualification Committee and has acknowledged the qualification of the Ariane 3 launch vehicle.

Industrial organisation

The management of the Ariane 2 and 3 development programme having been entrusted by ESA to CNES, the industrial organisation of the development phase remained essentially unchanged with respect the one established during the Ariane 1 development programme with the exception that ERNO and CONTRAVES became first level contractors and the Italian firm BPD (Bombrini Parodi Delfino) joined the programme, also as a first level contractor, for the development and manufacturing of the strap-on boosters.

The manufacturing and launching of all Ariane 2 and 3 vehicles is entirely under the responsibility of Arianespace.



4. General description of the Ariane 1 launch vehicle

Ariane is a three stage-launcher, carrying a vehicle equipment bay and nose fairing housing the payload. Lift-off mass is 209 tonnes. The launcher has a height of 47.4 m and a maximum diameter of 3.8 m.

Performance offers orbit injection for a wide range of payloads, from 4 tonnes heavy satellites placed in low altitude orbit to interplanetary probes. The ARIANE 1 performance is 1800 kg into the geostationary transfer orbit.

Each stage principally comprises :

. propellant tanks (or propellant and oxidizer tanks)
. one or more motors
. various items of electrical, mechanical or hydraulic equipment

The stages are coupled by means of interstage skirts, incorporating the pyrotechnic systems required for separation.

First stage

The first stage (height 18.4 m, diameter 3.8 m) is driven by four Viking V motors, developing a thrust (chamber pressure of 53,5 bar) of 2 462 kN on the ground (2 744 kN in vacuum), with a specific impulse of 248 s (281 s in vacuum).
The Viking motors use about 145 tonnes of storable propellants, these being Unsymmetrical Dimethyl Hydrazine (UDMH) and Nitrogen Peroxide (N_2 0_4). These propellants are carried in two identical steel tanks, cylindrical in form with semi-elliptical bulkheads, and coupled by an intertank skirt of the same diameter. A gas propellant mixture is used to pressurize the tanks. The nozzles of the four motors pivot in the plane tangent to the thrust frame, providing pitch, yaw an roll control. Aerodynamic stability during atmospheric flight is improved by four $2m^2$ fins. Burn-out occurs when either of the propellants is exhausted.

Second stage

This stage (height 11.5 m, diameter 2.6 m) uses a single Viking IV motor, developing in vacuum (chamber pressure : 53.5 bar) a thrust of 726 kN over 133 seconds of flight. Specific impulsion is 296.5 s. The motor is coupled to the thrust frame by a gimbal device with 2 degrees of freedom, for pitch and yaw control. The roll control function is provided by a set of independant nozzles, supplied with hot gas from the second stage gas generator.

The aluminium alloy tanks, carrying 34 tonnes of propellants, are pressurized with helium. The tanks form a cylindrical structure with hemispherical bulkheads divided into two chambers by an intermediate bulkhead also hemispherical and with its concave face upwards. Second stage burn is cut off when the on board computer detects achievement of the stage velocity increment. Simultaneously the computer initiates the stage 2 / 3 separation sequence. The second stage autodestucts about 30 s after separation.
During the waiting period on the launch pad before lift-off, the second stage tanks are protected by a thermal shield, the temperature of which is controlled with cool air, to limit heat exchange between the fuels and the ambient environment. The shield is jettisoned at liftoff.
In order to recover the V14 first stage from the sea, this stage is equipped with a telemetry system and 3 beacons for localization.

Third stage

The third stage (height 9.1 m, diameter 2.6 m) has one HM 7 motor, developing in vacuum (chamber pressure : 30 bar) a thrust of 61 kN with specific impulse 440.7 s. The motor pivots on the pitch and yaw axes by means of a gimbal device. Roll control is performed by an ancillary nozzles system supplied with hydrogen gas.

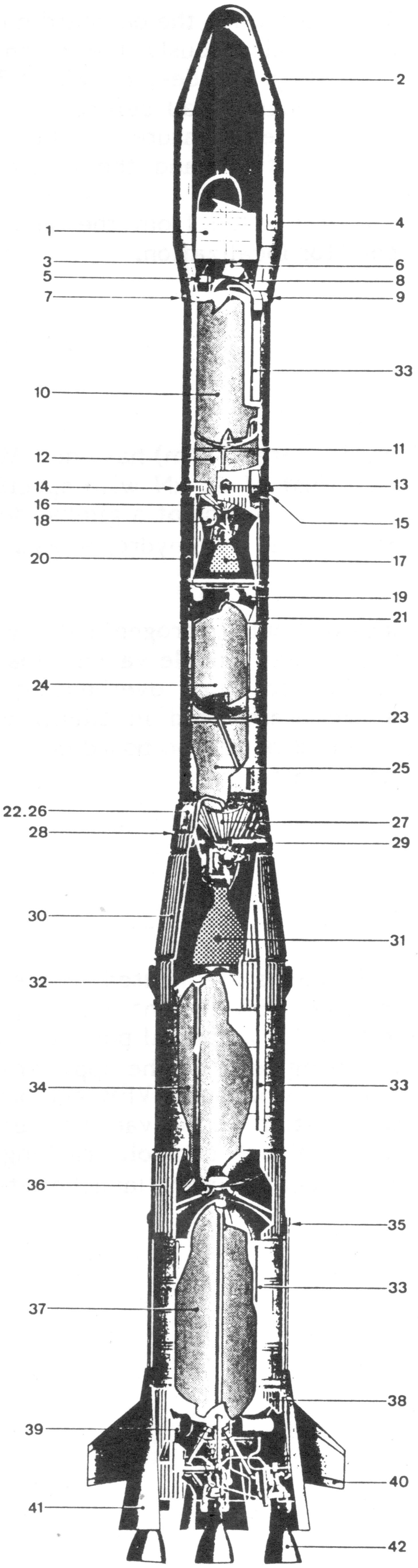
The two tanks holding 8 tonnes of liquid hydrogen and oxygen are in aluminium alloy, and have a common intermediate gulkhead (double vacuum loaded skin). The tanks are coated with external thermal protection to avoid overheating of the propellants. The liquid hydrogen and oxygen tanks are pressurized in flight, with hydrogen gas and helium respectively. Burn-out is controlled by the on board computer, using accelerometric data supplied by the inertial guidance platform.

Vehicle equipment bay

Most of the Ariane electrical sytems are housed in the Vehicle Equipment Bay (VEB), mounted on the third stage. The VEB (height 1.15 m, diameter 2.6 m) comprises a cylindrical shell, forming the base for a conical part, the upper frame of which is used to anchor the payload. The nose fairing rests on the upper frame of the cylindrical part. The conical shell carries the trays on which the VEB equipment is mounted. The on-board computer (OBC) coordinates operation of the various electrical systems of the launcher (sequencing unit, guidance and attitude control, tracking and telemetry systems). Only power and actuating systems are located in the launcher stages.

ARIANE 1

1	GIOTTO	
3	Third-stage / GIOTTO separation plane	*Plan de séparation 3ème étage / GIOTTO*
5	Equipment-bay subsystems	*Equipements case*
7	Vehicle equipment bay (VEB)	*Case à équipements*
10	Liquid-hydrogen tank	*Réservoir d'hydrogène liquide*
12	Liquid-oxygen tank	*Réservoir d'oxygène liquide*
14	Roll and attitude command system	*Système de contrôle attitude et roulis (SCAR)*
16	Third-stage thrust frame	*Bâti moteur du 3eme étage*
18	Helium pressurisation tank	*Sphère d'hélium de pressurisation*
20	Interstage 2-3	*Jupe inter-étages 2/3*
22	Second stage retro rockets (2)	*Fusées de freinage 2eme étage(2)*
24	N_2O_4 tank	*Réservoir N_2O_4*
26	Second stage acceleration rockets (4)	*Fusées d'accélération 2eme étage(4)*
28	1-2 separation plane	*Plan de séparation 1/2*
30	Interstage 1-2	*Jupe inter-étages 1/2*
32	First stage retro-rockets (8)	*Fusées de freinage 1er étage (8)*
34	N_2O_4 tank	*Réservoir N_2O_4*
36	Intertank skirt	*Jupe inter-réservoirs*
37	UDMH tank	*Réservoir UDMH*
39	First-stage torroidal water tank	*Tore d'eau du 1er étage*
41	Fairings	*Carénages*



2	Fairing	*Coiffe*
4	Fairing door	*Porte coiffe*
6	Payload adaptor	*Adaptateur charge utile*
8	Third stage sealing membrane	*Membrane d'étanchéité 3eme étage*
9	VEB antennae	*Antennes case*
11	Anti-sloshing device	*Anti-ballottant*
13	Third stage acceleration rockets (4)	*Fusées d'accélération 3eme étage (4)*
15	2/3 separation plane	*Plan de séparation 2/3*
17	Third-stage engine HM-7	*Moteur HM 7 du 3eme étage*
19	Helium pressurisation tanks (3)	*Sphères d'hélium de préssurisation (3)*
21	Second-stage front skirt	*Jupe avant du 2eme étage*
23	Anti-sloshing device	*Anti-ballottant*
25	UDMH tank	*Réservoir UDMH*
27	Second-stage thrust frame	*Bâti moteur du 2eme étage*
29	Second-stage torroidal water tank	*Tore d'eau du 2eme étage*
31	Second-stage engine -Viking IV-	*Moteur Viking IV du 2eme étage*
33	External cable duct	*Gouttière électrique*
35	N_2O_4 pipes (4)	*Canalisations N_2O_4 (4)*
38	First-stage thrust frame	*Bâti moteur du 1er étage*
40	Fins	*Empennages*
42	First-stage engines -4 Viking V-	*Moteurs Viking V du 1er étage*

Nose fairing

The Ariane 1 launcher nose fairing (height 8.65 m, cylindrical diameter 3.2 m), which protects the payload during the atmospheric flight, comprises two half-shell elements. The forward cone with its spherical nose cap is in light alloy protected by cork. The cylindrical part has a metal skin with stiffener frames and stringers. The rear boat-tail section reduces from a fairing diameter of 3.2 m to the 2.6 m of the VEB, and is constructed in radio-transparent materials. The nose fairing is fixed to the VEB by a clampband.

Separation systems

During the launcher mission, various masses the purpose of which has terminated must be jettisoned in flight. These operations include jettisoning the nose fairing at a certain altitude, and separation of each stage after burn-out.

The launcher has four separation systems, of which two are for inter-stage separation, one is for the nose fairing and one for the payload itself. Each separation sequence involves mechanical uncoupling of the two sections concerned, which must then move apart,or separate from each other. The systems used for the two inter-stage separations are similar.

Inter stage- separation

In each case, inter-stage separation occurs at a moment when launcher acceleration is practically nil. Mechanical disconnection is obtained by means of a pyrotechnic linear shaped charge fired simultaneously at two points. The cutting function is completed in less than 1 ms.

The two stages are separated from each other by ignition of retro rockets mounted on the lower stage, imparting acceleration opposed to launcher velocity.

During the separation phase, rockets are fired on the upper stage, imparting acceleration oriented to the launcher velocity. This action is designed to bring down the propellants ensuring correct feed to the upper stage motor, and also contributes to separation of the two stages.

Nose fairing jettisoning

The fairing is jettisoned during the second stage propulsion phase, with the launcher accelerating. After opening of the V-band clamping the fairing on the VEB, the two half-fairings are uncoupled from each other by a pyrotechnic system on their common generatrix, a parallel separating thrust being applied.

Launcher / payload separation

Payload separation is made after third stage burn-out, which is still under attitude control. The payload is released when the clampband is opened by firing a pyrotechnic system. Actual separation is produced by a set of 4 springs arranged on the periphery of the interface frame.

5. The ARIANE 4 programme

Trends in the use of space will lead to the launching of greater payloads as from 1986. It was accordingly decided to develop a more powerful version of Ariane - Ariane 4 -which is able to match a wide range of requirements.

The development of Ariane 4, which had been proposed to the ESA Council in October 1981, was formally approved in January 1982. The programme therefore started in early 1982 with the system studies and design phase. Early 1984 this programme entered the hardware and test phase.

Ariane 4 makes use of the development carried out under earlier programmes. The basic feature of this launcher is the existence of six different versions, with performances in geostationary transfer orbit between 1900 and 4200 kg. They will all have : a 1st-stage, lengthened by some 7 m, with a capacity of 226 tonnes of propellant, powered by four Viking engines operating at a chamber pressure of 58.5 bar ; a 2nd and 3rd stages identical with those of Ariane 3 subject to structural strengthening ; a new equipment bay on which can be fitted a new, large-diameter (4 m) fairing ; and a new device for multiple launches known as SPELDA (Structure Porteuse Externe pour Lancement Double Ariane -Ariane Dual Launch External Bearing Structure). The various versions differ according to the strap-on boosters fitted, namely :

- two or four solid propellant boosters derived from those of Ariane 3
- two or four liquid boosters each with some 40 tonnes of liquid propellants, using the Viking engine
- a hybrid version with two solid and two liquid boosters is also being developed, as well as one without any boosters

These Ariane 4 configurations (see page 33) will confer great flexibility, and will enable the launcher's performance to be matched to the payload, while keeping the occupancy rate high.

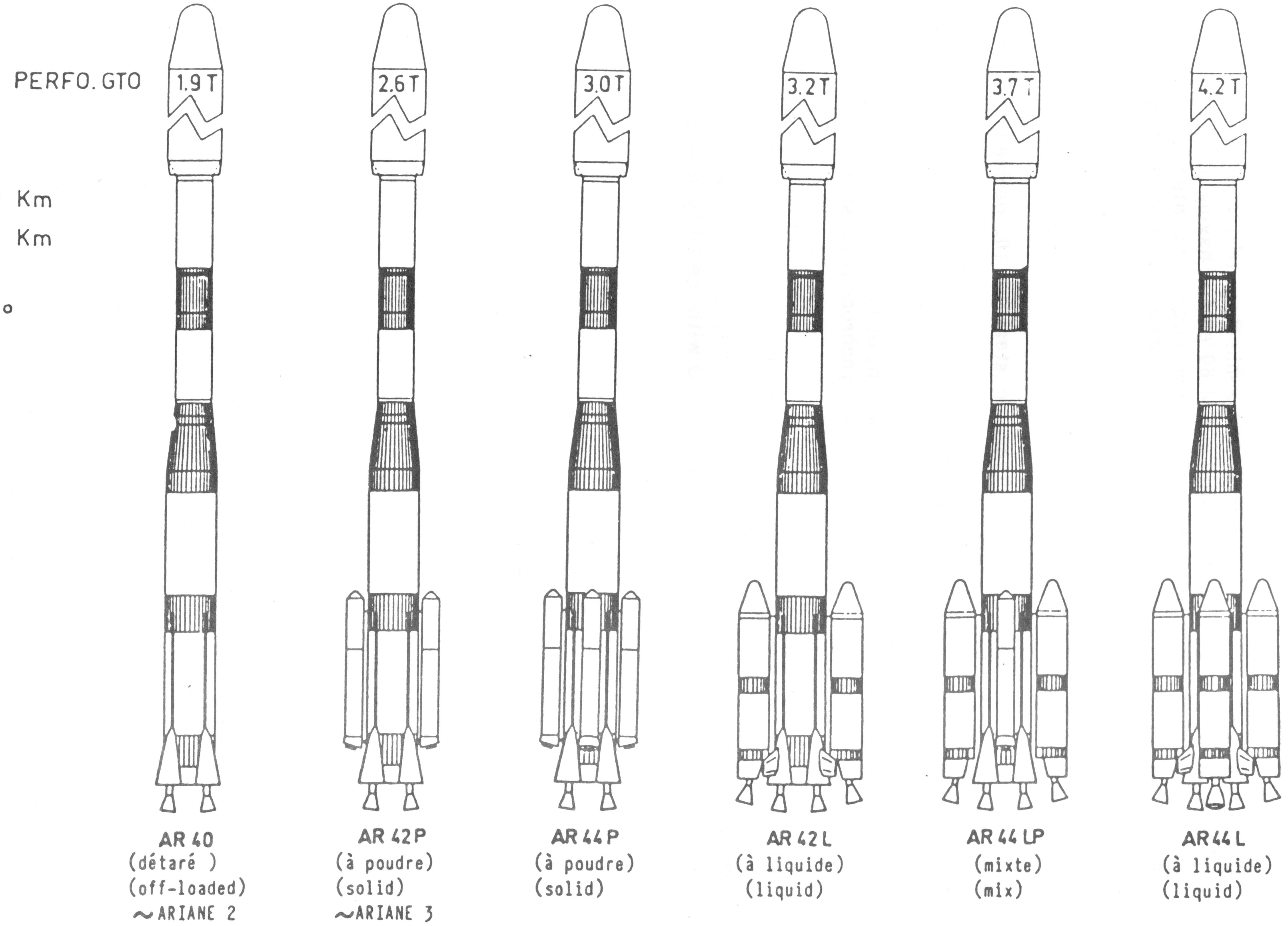
The performance in orbit of the ARIANE 4 various versions is shown below :

VERSION	MASS (kg)
AR 40	1 900
AR 42p	2 600
AR 44p	3 000
AR 42L	3 200
AR 44Lp	3 700
AR 44L	4 200

The programme will be concluded by a demonstration launch of an AR44LP vehicle, presently scheduled for mid 1986.

LES CONFIGURATIONS ARIANE 4
THE ARIANE 4 CONFIGURATIONS

Za 36000 Km
Zp 200 Km
i 7°
ω 178°



6. ARIANE 5

The proposed launch vehicle is a large cryogenic stage of 120 tonnes of propellants, having 5.4 meters in diameter, fitted with one HM 60 engine having a thrust of about 80 tonnes at lift off and 100 tonnes in vacuum, and two large segmented solid strap-on boosters, 3 meters in diameter, weighing around 170 tonnes of propellant and with more than 400 tonnes thrust at take off, each.

3 upper stages will be available, depending on the mission :

- for high energy mission, a cryogenic stage H 10, derived from the ARIANE 3 third stage,
- for low and medium energy automatic missions, a storable propellants stage (L4),
- for manned mission, Hermes with a weight of more than 16 tonnes for missions at low inclination, and about 13 tonnes for sunsynchronous missions.

A fairing will be used for automatic missions, with a diameter of 5.4 meters.

The performance of ARIANE 5 will be around 15 tonnes in low Earth orbit, 8 tonnes in GTO with the H10 type stage, 5 tonnes in GTO with the L4 type stage.

CHAPTER 3

THE LAUNCH FACILITIES

1. The Guiana Space Centre

1.1 History

1.2 CSG facilities

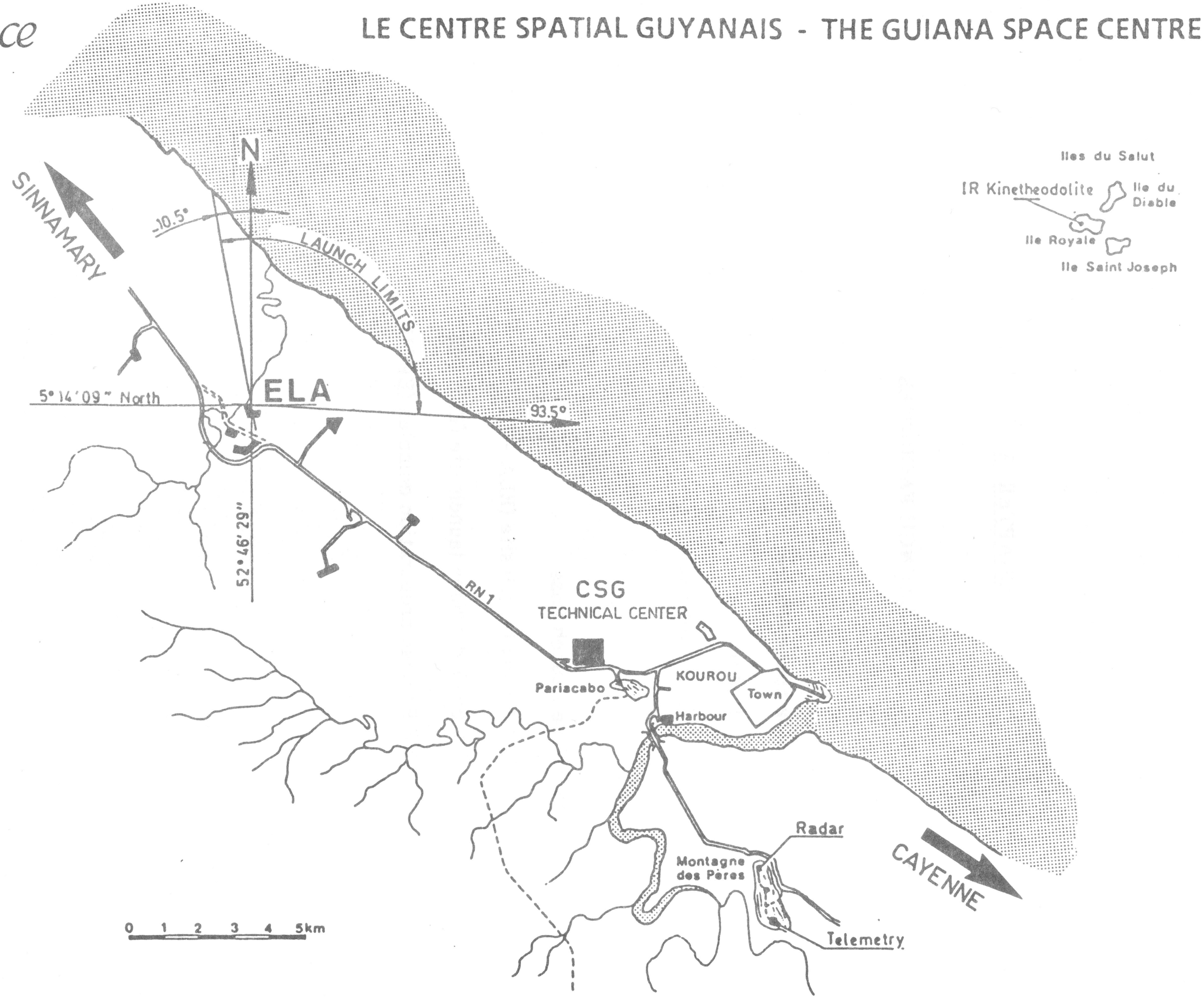
2. The Ariane Launch Base

2.1 Ariane launch site (ELA - 1)

2.2 Second Ariane launch site (ELA - 2)

2.3 Payload preparation complex (EPCU)

LE CENTRE SPATIAL GUYANAIS - THE GUIANA SPACE CENTRE



1. The Guiana Space Center

1.1 History

The decision to construct a new launch base in Guiana was taken in April 1964 by the French Government, which commissioned CNES to set up the Guiana Space Center (Centre Spatial Guyanais - CSG) at Kourou. The coastal strip of 30 km on either side of the Kourou river in French Guiana was chosen after a multi-criterion study in which fourteen possible sites were considered.

The site was selected on the basis of the following criteria :

- ability to launch towards the East and to have control over an area in which the first stage of the launcher could fall back without any danger ;
- location as close as possible to the Equator, in order to take advantage of the sling effect due to the Earth's rotation, and to allow an optimum procedure to be used for placing geostationary satellites in orbit (thanks to the slight inclination of the transfer orbit from the equatorial plane). The determining factors were the latitude (5.23° North) and the coastline, which allows launches between - 10.5° through North and + 93.5°.

The CSG became operational in 1968 with the launch of a sounding rocket "Véronique". After the "Diamant" programme (in which seven satellites were put into orbit), the CSG carried out launch operations for the Europa Vehicles and finally for ESA's Ariane, whose first launch took place successfully in December 1979.

1.2 CSG facilities

The CSG facilities extend from Kourou to Sinnamary over some 18 km of the Atlantic coast.

In the middle of this zone is the CSG Technical Center, the launch sites being situated some 12 km to the North-West of it. The telemetry and tracking radar facilities at Montagne des Pères and Montabo are located on small hills 10 km and 60 km South-East of the Technical Center.

CSG Technical Center

The Technical Center comprises the Management and Administrative Services, the CSG Technical Services, the Control Center from which the operational control of launches is exercised in real time and the clean rooms for non hazardous spacecraft preparation.

The launch sites

There are several launch sites within the CSG :

- the Sounding - rocket Launch Site ;
- the Diamant Launch Site (disused since 1976) ;
- the Ariane Launch Complex equipped with 2 launch sites, ELA 1 and the new ELA 2 site under construction.

Tracking system

The launch vehicle trajectory is determined by means of several radars and optical equipment (kinetheodolite) operated with computers. These facilities are located on various sites on the CSG and in the downrange stations.

The following are located at the CSG :

- 1 "Adour" radar for acquisition and close tracking, located at the meteorological station, 4 km from the Ariane Launch Site. It has a good range performance of 600 km,
- 2 "Bretagne" radars, for long range precision tracking up to 4000 km, located respectively near Kourou on the Montagne des Pères, 22 km from the Ariane Launch Site, and near Cayenne on Mount Montabo, 60 km from the launch site,
- 1 infrared tracker kinetheodolite located on the Royal Island (Iles du Salut) at 23 km from the ELA,
- in addition, fixed field optical cameras restitute the fine trajectory and the vehicle attitude between 0 and 100 meters.

The main computers at the Technical Center feed the plotting tables and television monitors at the Control Center, displaying the trajectory in real time, and also assign for the downrange tracking radars where on the horizon the launcher can be expected to appear.

For the eastwards launches, two downrange stations, one at Natal in Brazil and the other on Ascension Island (DOD/NASA radars), complete the tracking network, which provides complete coverage of the launcher during its boosted phase.

Telemetry system

The ground telemetry facilities receive the data transmitted by the Ariane Launch Vehicle. They comprise 4 stations and are designed to receive and record continuously all the data transmitted by the launcher during the powered phase of flight :

- the station, known as "Galliot" located on the Montagne des Pères can receive maximum six telemetries in E band (2 200 - 2 300 MHz) by means of 43 db antenna,
- the station at Natal in Brazil, is also fitted with a 43 db antenna,
- the NASA/DOD station on Ascension Island collects data on the last part of the vehicle trajectory until injection into orbit,

Flight safety facilities

The purpose of flight safety facilities is to monitor the launcher's movements in order to destroy it if it should constitute a hazard. For the first few hundred meters of trajectory, data from the telelimiters (television cameras) are used ; subsequently, the launcher's position determined by the tracking system is displayed on cathode-ray tubes as a projection on the ground ; for the last phase of the launch, the instantaneous impact point (in the event of thrust failure) is calculated from tracking - system data and displayed in real time.

All these data are displayed and evaluated in the flight-safety room, from which the Safety Officer can at any moment send the destruct order by means of a telecommand transmitter.

Coordination facilities

In order to make proper use of the CSG facilities, efficient coordination at the time of launch is required. To this end, the various sites are served by telecommunications facilities, status and intercom networks.

- the telecommunications network employs both cables and radio relay, used for transmitting operational data : television, telemetry and telecommand.
- the status and intercom networks provide operational communications and enable the Director of Operations (DDO) to coordinate and prepare launch operations.

2. The Ariane Launch Base

The Ariane Launch Base comprises two main elements :

- the Ariane Launch Sites (ELA 1 and ELA 2) lying within the CSG perimeter, which comprise the specific facilities needed for Ariane final assembly, checkout and launch operations ;
- the Payload Preparation Complex ("Ensemble de Préparation Charges Utiles" - EPCU) which comprises the spacecraft preparation facilities available to users.

The Ariane Launch Site n° 1 (ELA 1) is located about 18 km from Kourou town. Its purpose is to enable launches of Ariane to be carried out with the required safety, flexibility and efficiency.

The ELA 1 site is designed for six launches per year of the Ariane 1, Ariane 2 and Ariane 3 versions (i.e. a launch every two months).

The ELA 2 site is designed for launching the Ariane 2, Ariane 3 and Ariane 4 versions at a monthly rate.

2.1 First Ariane Launch Site (ELA 1)

ELA 1 comprises four distinct zones :

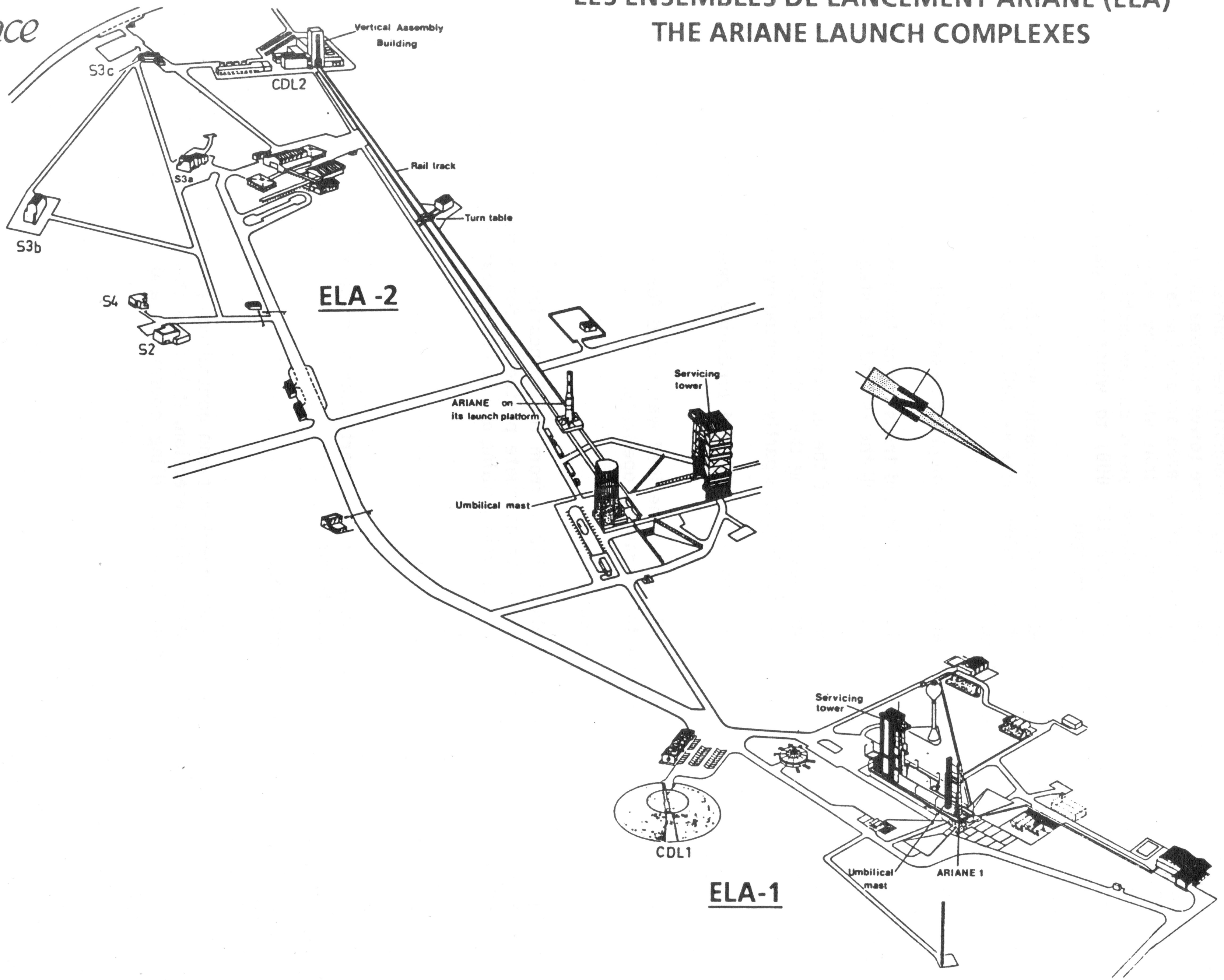
- the launch zone (ZL) which comprises the launch-pad area facilities and the Launch Center,
- the assembly zone (ZA) where the stages and elements of the launcher are stored in their containers, prior to erection,
- the propellant-support zone, with the analysis laboratory,
- the liquid-hydrogen and oxygen plant.

The launch zone comprises the main launch facilities : the launch-pad area (comprising in particular the servicing tower in which the launcher is erected and connected to its ground equipment) and the Launch Center, where nearly all checkout activities are conducted and operational control is exercised.

The launch-pad area comprises the following main elements :

- the foundation, which supports the launch table on which the launcher rests. A twin-slope jet deflector, with both surfaces faced with refractory concrete, forms an integral part of the foundation, and two half-buried flues canalise the 1st-stage engine exhaust at lift-off ;
- the launch platform, which provides access to the servicing tower, and over which the latter travels when it is withdrawn ; protected terminal facilities beneath the launch platform contain the equipment needed for launcher checkout and safety ;

LES ENSEMBLES DE LANCEMENT ARIANE (ELA)
THE ARIANE LAUNCH COMPLEXES



- the servicing tower, which is fully air-conditioned, moves back and forth on the launch platform. When fully advanced, the tower encloses the launcher on its table as well as the umbilical mast. The working area around the launcher is served by seven fixed platforms and a mobile platform that allows any level of the payload to be reached. A room inside the servicing tower, on the mobile platform (platform 8), constitutes the clean area (class 100 000) to which the payload for mechanical assembly with the launcher is brought.

- the umbilical mast, located behind the foundation and 6.20 m from the launcher axis. Its acts as a support for the umbilical arms as well as for the cable ducts, pipework and ground / launcher links.

- the peripheral equipment and buildings, comprising essentially :

  . two plants for discharging, storing and transferring the toxic propellants (UDMH and $N_2 0_4$) in quantities sufficient to fill the 1st and 2nd stages twice ;

  . two plants for storage and transfer of the cryogenic propellants, (liquid hydrogen and liquid oxygen) in quantities allowing the 3rd stage to be filled five times. For safety reasons, the LH_2 storage plant is partly protected by embankments ;

  . a plant for storing liquid nitrogen (LN_2) and producing gaseous nitrogen at high pressure ;

  . a plant for producing and storing the iced water used for air-conditioning all the faclities and for cooling the storable propellants.

  . a liquid helium evaporation facility.

- The launch Center, sited about 200 m from the foundation, is a heavily protected, blockhouse-type building providing adequate protection for personnel and checkout equipment during the final preparation, filling and launch operations.

  It provides protection against :

  . nearby explosion,

  . impact of fragments of stages and in particular of engines, in the event of the launcher being destroyed in flight,

  . toxic gases in the neighbourhood.

The Launch Center houses the check-out and control equipment for monitoring the launcher-preparation operations after erection. It is from this circular; underground building that the hazardous launcher filling operations and final activations are carried out before lit-off.

The assembly zone constitutes the "rear" logistics base for the launch-pad area. It consists essentially of :

- an assembly building, to which the Ariane stages are taken on their arrival in Guiana, for visual inspection and preparation prior to erection ;
- a stores building for site and launcher spares ;
- an office building ;
- a documentation building.

The propellant-support zone, which comprises two main storage facilities, two garages for tanker trailers and a propellant-analysis laboratory.

The liquid hydrogen and oxygen plant located in the Kourou industrial zone produces the quantities of these two cryogenic products needed to cover the Base requirements.

2.2 Second Ariane Launch Site (ELA 2)

The decision to create a second Ariane launch site ("Ensemble de lancement Ariane 2" - ELA 2) at Kourou was taken by ESA Member states in July 1981, with a view to operational availability mid 1985.

The main objectives of this programme are :

- to provide redundancy for the existing launch site (ELA 1) ;
- to increase operational flexibility and competitivity by :
  - reducing to 1 month the interval between two successive launches ;
  - optimising operating costs
- to develop the corresponding payload-preparation facilities.

ELA 2 is currently under construction close to the existing launch site (ELA 1), and will be suitable for launching the Ariane 2, 3 and 4 versions.
Essentially, it comprises two distinct zones : the launcher-preparation zone and the launch zone.

The launcher preparation zone is located at a safe distance (1 km) from the launch zone ; the following operations will be carried out there :

- launcher erection, up to equipment-bay level,
- checking the sealing of the various stages,
- electrical checks,
- remote checkout of the launcher during the launch countdown.

The launcher will spend about one month in this zone.

In the launch zone, which is likewise located at a safe distance from the existing launch site, ELA-1, the following operations will be conducted :

- final phase of launcher connection and checkout,
- mounting, assembly and checkout :
  - . of the Ariane 3 payload, and assembly of the Ariane 3 fairing,
  - . or of the encapsulated Ariane 4 payload.
- launch preparations,
- countdown and launch.

The launcher spends about 2 weeks in this zone.

For its move from the preparation zone to the launch zone, the launcher, assembled up to equipment-bay level, is placed upright on a launch table mounted on rail wheels which run on a double railway track. A turntable enables the launch tables to pass one another.

The distance between the launcher preparation zone and the launch zone ensures great flexibility in the use of the launch facilities, because one launcher can be erected, assembled and checked out in the preparation zone, while the previous launcher, which has been moved to the launch zone, undergoes the final preparations with a view to its imminent launch. The simultaneous use of the two zones - preparation and launch - of ELA-2 enables two launch campaigns to be conducted at once and reduces the interval between two successive launches to one month.
On completion under CNES management of the validation tests, ESA will make ELA-2 available to Arianespace in mid 1985.

2.3 Payload Preparation Complex (EPCU)

The EPCU comprises all the facilities made available by ESA to Ariane users for preparing their spacecraft, from the time of arrival in Guiana up to launch.

The EPCU is designed to prepare the launching of spacecraft compatible with the performance of Ariane, whether in single or dual launches.

The EPCU comprises several geographically dispersed buildings in areas corresponding to the activities to which they are assigned :

- Building S1A, located within the CSG Technical Centre, which is intended for the preparation and checkout of spacecraft. It provides a 480-m2 clean room, which can be shared for the simultaneous preparation of two spacecraft for dual launches. Suitable rooms (120 m2per spacecraft) are provided for setting up checkout equipment.
- Buildings S2 and S4, located in the ELA assembly zone, in which spacecraft solid-propellant boost motors are cooled, X-rayed and prepared for transport to building S3 for assembly with the spacecraft.
- Building S3A is used for filling 2 spacecraft with propellants for integrating the boost motors with the spacecraft and for dynamic balancing operations if requested. Three clean rooms (class 100 000) connected by 2 airlocks are used to perform these operations and the assembly of both spacecraft with the Ariane dual launch system Sylda.

Because of the increased launch rate that will be feasible when ELA 2 comes into service, and the larger spacecraft to be launched by Ariane 4 versions, the following buildings are being added to the EPCU facilities :

- Building S1B, commissioned in March 1985, is located at the CSG Technical Center in the immediate vicinity of the present S1A, and is used for the same tasks, having an 800 m2 clean room.

- Building S3B, planned for second half of 1985, is located in the Ariane Zone, close to the present S3A.

  It will be used for :

  . the filling of Ariane 4 large spacecraft

  . encapsulation of spacecraft within the AR 4 fairings and Spelda, the vertical combination thus formed being transported to the ELA 2 launch area for mounting on the launcher.

- Building S3C, operational from December 1984, situated close to the Ariane zone gate. It contains facilities for monitoring and controlling hazardous operations carried out in the S3A and S3B buildings.

CHAPTER 4

INFORMATIONS ON ARIANESPACE

1. Creation of the Company
2. Object of the Company
3. Agreement signed with ESA
4. The shareholders
5. Industrial production of ARIANE launchers
6. Services offered by ARIANESPACE
7. Selling prices
8. Contracts and options

1. Creation of the Company

ARIANESPACE, first commercial space transport company, was created on March 26th, 1980 by the 36 main European manufacturers in the aerospace and electronic industries, 13 important European banks, and the French Centre National d'Etudes Spatiales (CNES).

ARIANESPACE Limited Company has a joint stock of 120 million French francs (to be increased to 270 MFF) and is based at Evry (Essonne) near Paris. It employs about 200 people in Evry and 30 people in Kourou.

At the end of 1982, the company has established an office, in Washington D.C., to serve its North American clients.

2. Object of the Company

It assumes :

- overall production program management of the ARIANE operational launch vehicle and its uprated versions developed within the framework of the European Space Agency (ESA) ;

- financing of launch vehicles production ;
- marketing of the launching service throughout the world ;
- launching operations management at the Guiana Space Centre.

3. Agreement signed with ESA

In response to the spectacular development of space applications, ten European countries : Belgium, Denmark, Federal Republic of Germany, France, Italy, Netherlands, Spain, Sweden, Switzerland, the United Kingdom decided in Brussels on July 31 1973, to jointly build a heavy launch vehicle for application satellites : ARIANE.

This programme, carried out under the aegis of the European Space Agency (ESA) was financed by the participating European states.

Under the direction of the French Centre National d'Etudes Spatiales (CNES), the launch vehicle is manufactured by the electronic and aerospace industries of the participating countries. Ireland joined the programme in 1978.

Following the coming into effect of an intergovernmental agreement, the European Space Agency's member States have transfered to ARIANESPACE the responsibility for the production, marketing and launching of operational Ariane vehicles and their uprated versions.

Under this decision, a convention signed on May 15th, 1981 between ESA and ARIANESPACE assesses the clauses of this transfer and more particularly the utilization conditions of the production tool and the launch means set up in the ARIANE development programme.

A procedure for concertation is also included in the agreement between ARIANESPACE and ESA which remains responsible for the development of new versions for the ARIANE series.

4. The shareholders

The shareholders' participation is broken down as follows :

GERMAN SHAREHOLDERS 19.60 %

DORNIER
MBB/ERNO
MAN
BAYERISCHE VEREINSBANK A.G.
DRESDNER BANK
WESTDEUTSCHE LANDESBANK GIROZENTRALE

BELGIAN SHAREHOLDERS 4.40 %

ETCA
FABRIQUE NATIONALE HERSTAL
SABCA

DANISH SHAREHOLDERS 0.70 %

Christian ROVSING AS
COPENHAGEN HANDELSBANK

SPANISH SHAREHOLDERS 2.50 %

CASA
SENER

FRENCH SHAREHOLDERS 59.25 %

AEROSPATIALE
AIR LIQUIDE
COMSIP-ENTREPRISE
CNES
CROUZET
DEUTSCH
INTERTECHNIQUE
MATRA
SAFT
SEP
SFENA
SFIM
SODETEG
CREDIT LYONNAIS
BNP
BANQUE VERNES
OPFI Paris Bas
SOCIETE FINANCIERE AUXILIAIRE
VALORIND

BRITISH SHAREHOLDERS 2.40 %

AVICA
BADG
FERRANTI
MIDLAND BANK Ltd

IRISH SHAREHOLDERS 0.25 %

ADTEC TEORANTA
AER LINGUS

ITALIAN SHAREHOLDERS 3.60 %

AERITALIA
SNIA - BPD
SELENIA SPAZIO
SI-EL-SPA

DUTCH SHAREHOLDERS 2.20 %

FOKKER
ALLGEMENE BANK NEDERLAND

SWEDISH SHAREHOLDERS 2.40 %

SAAB-SCANIA
VOLVO

SWISS SHAREHOLDERS 2.70 %

CIR
CONTRAVES
FABRIQUE FEDERALE D'AVIONS
UNION DES BANQUES SUISSES

5. Industrial production of ARIANE launchers

The ARIANESPACE company is responsible for the industrial management of the production of ARIANE launch vehicles. It works in conjunction with seven industrial companies, to whom the following responsibilities are assigned by contract :

- AEROSPATIALE is responsible for the 1st and 3rd stages, and acts as the industrial designer ;
- SEP is responsible for the propulsive systems for the three stages ;
- MBB/ERNO is responsible for the 2nd stage ;
- MATRA is responsible for the equipment bay ;
- CONTRAVES is responsible for the fairing ;
- AIR LIQUIDE is responsible for the 3rd stage tanks ;

For ARIANE 3 and 4 configurations :

- SNIA - BPD is responsible for the production of the solid strap-on boosters.

For ARIANE 4 configuration :

- MBB/ERNO is responsible for the production of the liquid strap-on boosters.

The contractors listed above sub-contract a considerable proportion of production work to firms located in the 11 countries participating in the ARIANE programme.

ARIANESPACE also co-ordinates unpredictable customer demand with the industry's need for well-defined production rate. ARIANESPACE must decide to product new launch vehicles in anticipation of new firm orders and at what point production rates must be increased.

Initially, ARIANESPACE has set the production rate for launch vehicles at one vehicle every two and a half months, in order to satisfy orders and options already accepted. Further investments have increased the production rate up to one launcher every two months.

The launch rate is being gradually increased from 4 to 5 in 1984 to 6 to 8 in 1987, with an annual turnover between 2.5 and 3 billion French Francs.

Till now, ARIANESPACE has ordered to its suppliers 25 launch vehicles in addition to the 10 launch vehicles manufactured for the development launches and the promotional series.

1	ARIANE 1
17	ARIANE 2 and 3
7	ARIANE 4

ARIANESPACE also has ordered long term supplies for 6 additional launch vehicles.

Over 6 000 people are working today in Europe on the ARIANE programme (production and development). With the increase of the production rate in the next years and the new developments, 10 000 people will be working in the European Space Industry before the end of the decade.

6. **Services offered by ARIANESPACE**

. Arianespace is the first private space transport company. Company organization is flexible and adapted to customer needs.
For a flat rate price, Arianespace provides the customer with a complete set of services, covering all operations from the arrival of the satellite and its associated equipment, to actual injection into GTO, including positioning, spin-up (where required) and separation tasks. This price also includes any studies which may be required, and adaptation of the launcher where appropriate, to ensure total satellite/launcher compatibility.

. The concept of direct, flexible interface control goes together with the idea of a complete launch service. For all aspects of the launch service, the customer is involved with only one interface, one official contact, this being Arianespace responsible for payload transport from the ground to the orbit requested.

. Arianespace uses modern, customized resources :

- high performance launcher, enabling customers to utilize the true capacity of their satellites to the full, with consequently optimized operational lifetime.

  As a result of the orbit injection accuracy of the launcher, the customer can further extend the applicational range of his satellite.

- Arianespace offers a comprehensive launcher family, fully adapted to satellite mass increases and evolution of the market, capable of launching any existing or projected civil satellite. This degree of Ariane launcher adaptability is achieved by modular first stage design, making it possible to obtain optimum compatibility between performance and payload capacity for Ariane 4.

- modern, favourably situated launch site, with satellite preparation facilities compatible with a launch rate of 10 per year.

- very short launch program duration in Guiana, generally not exceeding 28 working days for the launcher. Furthermore, the launcher only requires satellite availibility 7 to 9 days ahead of launch date. Satellite launch program time can thus be reduced to a strict minimum.

Arianespace, by its creation and subequent action, has introduced a competitive situation in the world space transport market, for the greater benefit of the user. Arianespace has set out to provide a maximum level of launch services availibility, and a high degree of operational flexibility, with the objective of maximum customer satisfaction.

7. Selling prices

ARIANESPACE bills in F.F. and D.M. or U.S. $ and calculates selling prices in accordance with the following considerations :

- launching date
- performances
- technical options
- payment plan
- billing currency
- basic economic conditions

In 1985, and taking account of the previous parameters, the prices are 25-30 million U.S. dollars per satellite, for a dual launch by ARIANE 3 (2 satellites of PAM-D class).

8. Contracts and Options

The total amount of firm contracts comes to 32 satellites (of which 9 have been launched already) corresponding to 7,6 billion French Francs (44 % outside Europe). Moreover Arianespace has obtained 16 options.

ARIANESPACE BACKLOG
AS OF MAY 9th, 1985

23 SATELLITES FOR 6 BILLION FRANCS

EUROPE = 14 SATELLITES

- *Kopernikus-1 & 2*
- *ECS-3*
- *Giotto*
- *Meteosat-1, 2 & 3*
- *Olympus (L-Sat)*
- *Spot-1 & 2*
- *TDF-1*
- *Tele-X*
- *TV-Sat-1*
- *Viking*

60 %

OUTSIDE EUROPE = 9 SATELLITES

U.S.A.	*International Organizations*	*Others*
G-Star-II		
SBS-5	*Intelsat-VA, F13, F14, F15*	*Aussat-3 (Australia)*
Spacenet-F3	*Intelsat-VI-F3*	*Brasilsat-S2 (Brazil)*

40 %

RESERVATIONS
ON THE ARIANE LAUNCH VEHICLE

16 SATELLITES

EUROPE = 10 SATELLITES

- *Coronet*
- *ECS-4*
- *ERS-1*
- *Hipparcos*
- *Italsat*
- *TDF-2*
- *Telecom-1C*
- *TV-Sat-2*
- *Unisat-1 & 2*

OUTSIDE EUROPE = 6 SATELLITES

- *Anik*
- *CBSC-1 & 2*
- *DBSC-1 & 2*
- *Intelsat-VI-F4*

May 1985
DC-757-MK

FIRM LAUNCH CONTRACTS REGISTERED BY ARIANESPACE

32 SATELLITES FOR 7,6 BILLION FRANCS

EUROPE = 18 SATELLITES

- *Kopernikus-1 & 2*
- *ECS-2* & 3*
- *Giotto*
- *Marecs-B2**
- *Meteosat-1, 2 & 3*
- *Olympus (L-Sat)*
- *Spot-1 & 2*
- *TDF-1*
- *Telecom-1A* & 1B**
- *Tele-X*
- *TV-Sat-1*
- *Viking*

56 %

OUTSIDE EUROPE = 14 SATELLITES

U.S.A.	*International Organizations*	*Others*
G-Star-I & II*	*Intelsat-VA, F13, F14, F15*	*Aussat-3 (Australia)*
SBS-5	*Intelsat-VI-F3*	*Arabsat-1A* (Arabic Countries)*
Spacenet-F1, F2* & F3*		*Brasilsat-S1* & S2 (Brazil)*

44 %

** Satellites already launched.*

RESERVATIONS ON THE ARIANE LAUNCH VEHICLE

16 SATELLITES

EUROPE = 10 SATELLITES

- *Coronet*
- *ECS-4*
- *ERS-1*
- *Hipparcos*
- *Italsat*
- *TDF-2*
- *Telecom-1C*
- *TV-Sat-4*
- *Unisat-1 & 2*

OUTSIDE EUROPE = 6 SATELLITES

- *Anik*
- *CBSC-1 & 2*
- *DBSC-1 & 2*
- *Intelsat-VI-F4*

May 1985
DC-758-MK

Evry, May 1985

arianespace

Satellite	CLIENT	Manufacturer	Mission
ARABSAT	Arabsat Satellite Communication Organisation (Arabian League)	AEROSPATIALE	(1) + (2)
AUSSAT	Aussat (Australia)	HUGHES AIRCRAFT CORP.	(1) + (2)
BRASILSAT	Embratel (Brazil)	SPAR	(1) + (2)
DFS-KOPERNIKUS	Deutsche Bundespost (F.R. of Germany)	MBB	(2)
ECS	European Space Agency for Eutelsat	BAe	(1) + (2)
GIOTTO	European Space Agency	BAe	(3)
G-STAR	G.T.E./Spacenet (U.S.A.)	RCA ASTRO ELECTRONICS	(1) + (2)
INTELSAT V	Intelsat	FORD AEROSPACE COM.CORP.	(1) + (2)
INTELSAT VI	Intelsat	HUGHES AIRCRAFT CORP.	(1) + (2)
MOP (Meteosat Operationnel)	European Space Agency for Eumetsat	AEROSPATIALE	(4)
OLYMPUS	European Space Agency	BAe	(1) + (2)
SBS	Satellite Business Systems (U.S.A.)	HUGHES AIRCRAFT CORP.	(2)
SPACENET	G.T.E./Spacenet (U.S.A.)	RCA Astro Electronics	(1) + (2)
SPOT	Centre National d'Etudes Spatiales (France)	MATRA	(5)
TDF	CNES for Télédiffusion de France (France)	EUROSATELLITE	(1)
TELECOM	Direction Générale des Télécommunications (France)	MATRA	(1) + (2)
TELE-X	Swedish Space Corp. (Sweden)	AEROSPATIALE	(1) + (2)
TV-SAT	Bundesministerium für Forschung und Techn. (F.R. of Germany)	EUROSATELLITE	(1)
VIKING	Swedish Space Corp. (Sweden)	BOIENG	(3)

(1) Television
(2) Telecommunications
(3) Science
(4) Meteorology
(5) Earth Remote Sensing

CHAPTER 5

GIOTTO : ESA'S MISSION TO HALLEY'S COMET

GIOTTO: ESA'S MISSION TO HALLEY'S COMET

July 1985 - March 1986

THE MISSION

The present apparition of Halley's Comet is the fourth predicted apparition of this comet and it is the first opportunity for spacecraft to be sent to Halley to observe the comet from close-by and to carry out measurements in the cometary atmosphere. Among 1000 known comets, Halley is the most outstanding target because it is the only highly active comet with a well-known orbit. The Giotto mission to Halley's Comet is ESA's first interplanetary mission and ESA's first mission involving an encounter with a solar system body. The mission was named "Giotto" after the Florentine painter Giotto di Bondone who saw Halley's Comet in 1301 and incorporated it a few years later realistically as the Star of Bethlehem in a painting the "Adoration of the Magi" which is a tier in a fresco cycle decorating the interior of the Scrovegni chapel in Padua.

Although comets are among the most spectacular objects in the sky, although they have been observed for many thousand years and although they occasionally come very close to the Earth, very little is known about them. Most of our "knowledge" is based on circumstantial evidence. An encounter with a comet is one of the few exploratory missions left in the solar system where major surprises can still be expected. Comets have preserved the records of the early history of the solar system: the chemical composition and isotopic ratios of cometary material have changed very little since the formation of the solar system 4.6 billion years ago, because comets have spent almost all of their lifetime in a "deep freeze" at about 50 000 AU* away from the Sun.

Occasionally, the orbit of a comet is changed by chance gravitational perturbations of the nearest stars and the comet may be deflected into the inner solar system, where it can be observed. The comet's nucleus consists of a mixture of ices and solid material in the form of dust and grains, which can best be described as a "dirty snowball". On approaching the Sun, it is heated and releases enormous amounts of dust and gas. The nucleus, a body only a few kilometres in diameter, produces a coma which can be more than 100 000 km in extent. The neutral gas is ionised by solar ultraviolet radiation and probably also by electrons, and the ions are swept by the solar wind in the anti-solar direction to form a narrow, straight ion tail. Solar radiation pressure forces the dust particles, in particular the smaller ones, also into the anti-solar direction. Since the dust particles have far lower velocities than the ions and cover a wide spectrum of particle sizes, the dust tail is curved and broad. What is visible and known as "the comet" is in fact the sunlight scattered by the dust particles and line emission from neutral particles and ions excited by sunlight (fluorescence).

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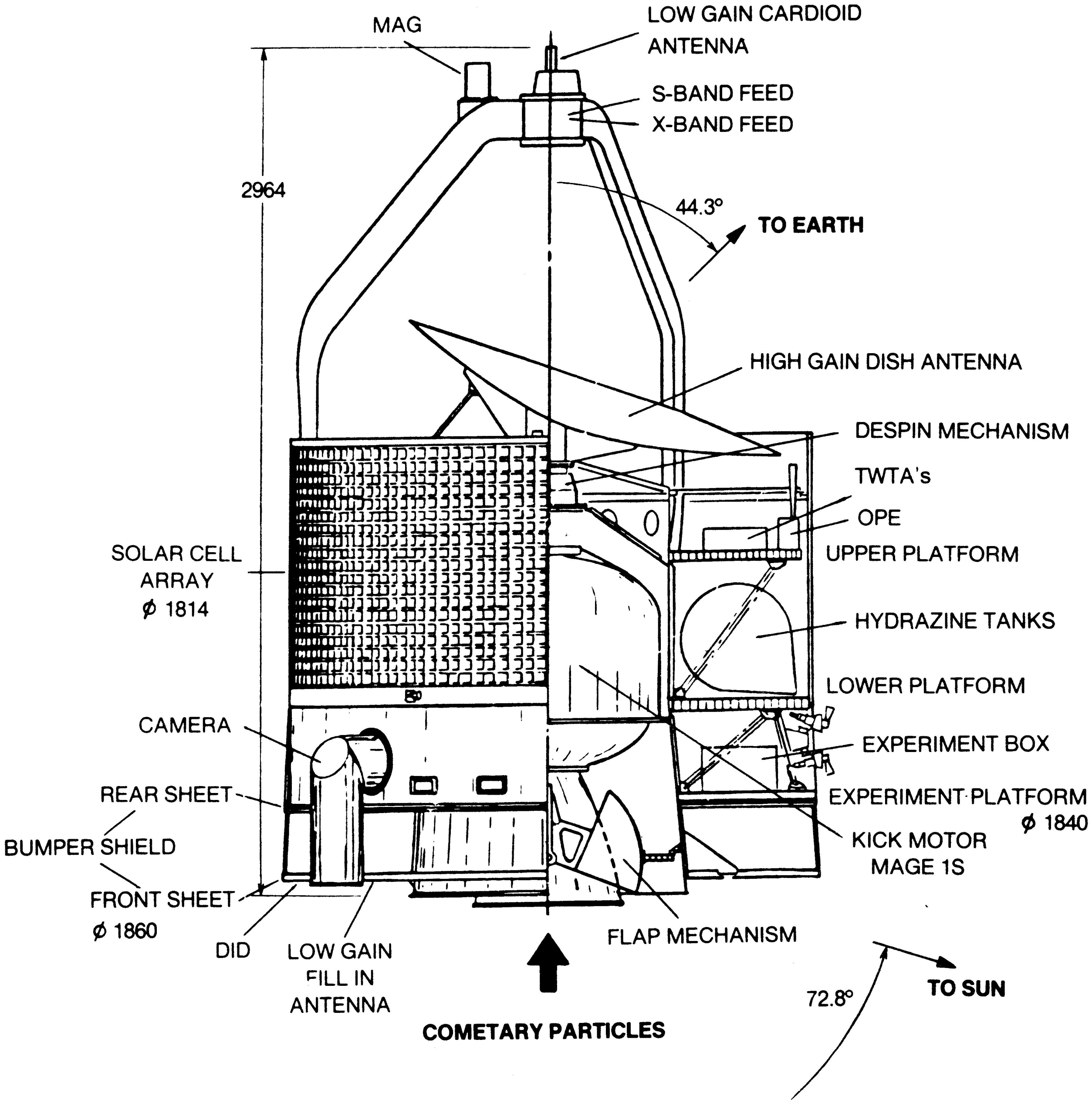
* 1 AU (Astronomical Unit) corresponds to 150 million kilometres

THE SPACECRAFT

Giotto is a spinning spacecraft (15 rpm). Its cylindrical body is 1.84 m in diameter and 1.6 m high, with a tripod on top to carry the magnetometer sensor and the antenna feed. The spacecraft weighs 960 kg at launch which reduces to 512 kg during the encounter when the onboard solid propellant kick motor has burnt out and the hydrazine has been used up for the various mid-course attitude and orbit correction manoeuvres. The side that faces the comet during the encounter is protected from hypervelocity dust impacts by a dual-sheet bumper shield. The high gain dish antenna at the other end is despun and inclined to point at the Earth during the encounter. All experiments are mounted on the lowest of 3 platforms, the "experiment platform", they are protruding sidewards and look towards the comet. The spacecraft power is derived from a solar cell array and 4 batteries. All data are transmitted to Earth in real time, at a rate of 40 kilobits per second.


MAG
LOW GAIN CARDIOID ANTENNA
S-BAND FEED
X-BAND FEED
2964
44.3°
TO EARTH
HIGH GAIN DISH ANTENNA
DESPIN MECHANISM
TWTA's
OPE
UPPER PLATFORM
SOLAR CELL ARRAY
ϕ 1814
HYDRAZINE TANKS
LOWER PLATFORM
CAMERA
EXPERIMENT BOX
REAR SHEET
EXPERIMENT PLATFORM
ϕ 1840
BUMPER SHIELD
KICK MOTOR
MAGE 1S
FRONT SHEET
ϕ 1860
DID
LOW GAIN FILL IN ANTENNA
FLAP MECHANISM
COMETARY PARTICLES
72.8°
TO SUN

The Giotto project was approved in July 1980 by ESA's Science Programme Committee.

The procurement programme involved three spacecraft models:

	The Structure Model (completed mid-1983)	for testing the mechanical integrity of the design
.	the Electrical Model (completed Feb. 1984)	for testing the electrical functional design compatibility
.	the Proto Flight Model (delivery April 1985).	for flight qualification and flight

During the early part of 1985 system level testing was completed at the Intespace facility in Toulouse (France) where all experiments were integrated and tested on system level. Subsequent to system level testing several instruments were returned to the experimenter's institutions for final adjustments prior to shipment to the launch site.

The spacecraft was accepted by ESA from the prime contractor BAe on 22 April 1985 and subsequently shipped to the launch site, at the Guiana Space Centre (CSG), Kourou, on 29 April 1985.

Upon arrival the spacecraft was immediately installed at the new S1B clean room integration and test facilites at CSG and integrated with the electrical test equipment for the start of the launch campaign check out. The launcher was integrated with the spacecraft in June 1985.

THE SCIENCE

The comet nucleus cannot be seen from Earth even with the best telescopes, because it is too small and furthermore obscured by the dust and gas in the coma. Therefore a prime objective of the mission to Halley is to detect the comet nucleus. The camera onboard Giotto will take numerous colour pictures of the nucleus (about one every 4 seconds) during the flyby ; the best pictures could be taken from a distance of less than 1 000 km and would have a resolution of better than 22 m per pixel. A point of intense discussion is the question of nucleus visibility. Close to the nucleus where the dust particles have not yet attained their full escape velocity, their density may be so high that the atmosphere may be optically thick.

Another prime objective of the mission is to measure the elemental and isotopic composition of the cometary neutrals, ions and dust particles, using three specifically designed mass spectrometers. From these measurements the complex physical and chemical processes that occur in the cometary atmosphere can be derived. It should then be possible to identify the "parent molecules", those molecules of which the comet nucleus is made. The interaction of the solar wind plasma with the cometary ionosphere bears some resemblance to the interaction of the solar wind with planetary magnetospheres, but the extremely different ratios of dimensions of the parent body to the ionosphere, the bow schock and the tail give ample scope for the development of novel behaviour. Various plasma experiments and a magnetometer on board Giotto will study these effects. The scientific payload is further complemented by impact sensors for measurements of the mass spectrum of dust particles and by an optical probe for measurements of the spatial distribution of dust particles and of various selected gaseous emissions. In all Giotto will carry 10 experiments with a total mass of 58 kg. In addition, there is the possibility that a radio science experiment, measuring the total electron content and the deceleration of the spacecraft will be carried out. In total, there are 87 participating institutes involving over 200 scientists from all ESA Member States, together with 40 from the USA.

The scientific objectives of the Giotto mission are to :

- provide the elemental and isotopic composition of the volatile components in the cometary coma, in particular to identify the parent molecules,

- characterise the physical processes and the chemical reactions that occur in the cometary atmosphere and ionosphere,
- determine the elemental and isotopic composition of the cometary dust particles,
- measure the total gas production rate and the dust flux and size/mass distribution and to derive the dust-to-gas ratio,
- investigate the macroscopic system of plasma flow resulting from the interaction between the cometary and solar-wind plasma,
- provide numerous images of the comet nucleus with a resolution down to 50 m. From these the nucleus size and rotation may be deduced and its mass may be estimated.

THE SCIENTIFIC PAYLOAD

The ten experiments comprising the Giotto payload are summarised below:

THE HALLEY MULTICOLOUR CAMERA (HMC)

The camera is designed to detect and take four-colour images of the nucleus of Comet Halley. By following the moving comet nucleus, the camera's microcomputer can determine the trajectory parameters of the spacecraft relative to the nucleus in real time.

The optical system of the camera is a modified Ritchey-Chrétien design with correcting field lens. The telescope, which has a focal length of 1 m (f/6.25, effective f/7.68), is mounted behind the spacecraft bumper shield and is therefore protected from direct dust-particle impacts. A 45° deflecting mirror is used to look at the comet. A baffle approximately 450 mm long assures adequate reduction of diffuse sunlight and spacecraft-reflected light. The telescope images onto a focal-plane arrangement of one Reticon and two area CCD's (charge-coupled device) which are highly sensitive devices used now days in modern astronomy.

The camera can be rotated through 180°, allowing the nucleus to be followed during approach and imaged even after the flyby. Already at 1400 km from the nucleus, the camera will be able to resolve its surface structure down to 30 m and at 500 km the resolution will be about 10 m.

Besides the fascination of "seeing" the nucleus of a comet for the very first time, the images will provide scientists with information on the shape of the nucleus and on variations across its surface, especially if there are just a few active "hot spots" of emission producing the dust and gas jets observed in the coma.

The images will also enable scientists to determine the size, rotation period and axis of the nucleus and to estimate its mass.

THE NEUTRAL MASS SPECTROMETER

This experiment will measure the elemental and isotopic composition and the abundances and energy distributions of the neutral gases in the cometary coma. The molecules released from the nucleus ("parent molecules") undergo a complex chain of chemical reactions which has the effect that the composition changes with distance from the nucleus. For mass spectrometric analysis the gases have to be ionized which is achieved by bombarding the neutrals with an electron beam. Masses and energies are then determined by their deflection in the electric and magnetic fields of the experiment which has two independent sensors: the M-analyser provides mass analysis in the range 1-36 amu, the E-analyser provides energy analysis in the range 24 - 2100 eV. Above 36 amu the neutrals are assumed to be thermally cold and consequently, the energy measured by the E-analyser corresponds to a mass measurement up to 86 amu.

ION MASS SPECTROMETER

The Ion Mass Spectrometer comprises two sensors, a High Energy Range Spectrometer (HERS) optimised for measurements in the outer coma where a turbulent transition between solar wind and cometary ions is expected, and a High Intensity Spectrometer (HIS) optimised for measurements in the inner coma where high fluxes of relatively cold cometary ions are expected.

HIS looks essentially forward while HERS looks sideways; HIS is optimised to measure the high-density fluxes in the inner coma while HERS is designed to measure the more reduced ion densities in the outer coma.

DUST MASS SPECTROMETER

This instrument measures the chemical and isotopic compositions of individual dust particles. When a dust particle strikes the instrument's target, a plasma is generated from which ions are extracted and accelerated via a 1.5 kV acceleration grid. The accelerated ions fly through a time-of-flight tube approximately 1 m long, where they are separated in time according to their mass. The spectrum of elements of which the dust particle is composed is recorded by an electron multiplier at the end of the drift path.

Because of its small target area, the instrument will predominantly analyse the most common dust particles, which are expected to be in the mass range 10^{-14} to 10^{-10} g.

DUST IMPACT DETECTION SYSTEM (DIDSY)

This system consists of a variety of sensors to measure the dust mass distribution over a very wide range (10^{-18} - 10^{-3} g), from dust particles smaller than the particles smoke consists of up to pea-sized particles. Impacts of large dust particles will be detected by three piezo-electric transducers ("microphones") mounted on the outer face of the front sheet of the bumper shield. The amplitude of the wave generated upon impact is proportional to the particle's mass. An identical detector, mounted on the rear sheet, will detect impacts of even larger particles which are able to penetrate the front sheet. A Capacity Impact Sensor will register impacts of dust particles above a threshold of 10^{-10} g, while an Impact Plasma Detector will detect impacts of very small particles. Upon impact on the gold foil of the detector a small dust particle is ionised and the total charge of the plasma corresponding to the particle's mass is measured. The Impact Plasma Detector is combined with an additional microphone for cross-calibration. During the encounter in March 1986 the impacts of the dust particles on the spacecraft will be made audible in ESOC.

THE OPTICAL PROBE EXPERIMENT

This experiment uses a small refracting photopolarimeter with an objective lens of 24 mm diameter, eight interference filters, two spectrally matching polaroid foils and a microchannel plate for spectral analysis. The experiment, which looks straight back along the spacecraft's trajectory, provides in-situ observations of the spatial density of dust and gas and of the scattering properties of dust grains. The dust will be observed in four spectral bands which are free or almost free of gaseous emissions. Simultaneously, the discrete gaseous emissions of OH, CN, $CO+$ and C_2 will be observed.

The payload is completed with a series of 6 different plasma experiments designed to investigate the interaction of the solar wind with the cometary ionsophere.

1. A 'Fast Ion Sensor' measures the three-dimensional velocity distribution of positive ions resulting from the solar-wind comet interaction in the energy range 10 eV-20 keV.

2. An 'Implanted Ion Sensor' measures cometary ions with energies up to 70 keV implanted in the solar wind. Some cometary neutrals can travel large distances from the nucleus before they are ionised by charge exchange or photo-ionisation.

3. An 'Electron Electrostatic Analyser' measures the pitch-angle distributions for suprathermal electrons in the energy range 0.01-30 keV.

4. A 'Positive Ion Cluster Composition Analyser' measures singly charged, high-mass positive ions such as "clathrate hydrates" in the innermost part of the coma.

5. An 'Energetic Particle Experiment' which consists of three identical very small telescopes, each with two solid-state detectors, two (one with and one without a foil to provide electron/proton separation) mounted side by side at 45°, and one mounted at 135° with respect to the spin axis. This experiment measures the energy and spatial distribution of protons and electrons $>$ 15 ke V.

6. The ambient magnetic field is measured by a wide-range triaxial ring-core fluxgate 'Magnetometer', employing two sensors mounted on the antenna tripod.

Table 2: GIOTTO SCIENTIFIC PAYLOAD (November 1984)

Experiment		**Mass (kg)**	**Power (W)**	**Data Rate (bps) Format 1/2/3***			**Principal Investigator**	**Main Collaborating Institutes (hardware)**
Camera		12.605	9.4	20058		723	H. U. Keller MPI für Aeronomie Lindau W. Germany	Laboratoire de Physique Stellaire & Planétaire, Verrières-le-Buisson; Institut d'Astrophysique, Liège; Istituto di Astronomia, Padova; DFVLR, Oberpfaffenhofen; Ball Aerospace Systems Division, Boulder;
Neutral Mass Spectrometer	M-Analyser E-Analyser	12.578	10.7	4156		-	D. Krankowsky MPI für Kernphysik Heidelberg W. Germany	Physikalisches Institut, University of Bern; Laboratoire de Géophysique Externe, CNRS, Saint-Maur; The University of Texas at Dallas;
Ion Mass Spectrometer	High Energy Range Spectrometer, High Intensity Range Spectrometer	9.003	10.45	3253		1084	H. Balsiger Physikalisches Institut University of Bern Switzerland	MPI für Aeronomie, Lindau; JPL, Pasadena; Lockheed Palo Alto Research Laboratory;
Dust Mass Spectrometer		9.802	10.3	2891	5782	-	J. Kissel MPI für Kernphysik Heidelberg W. Germany	
Dust Impact Detector System	Meteoroid Shield Momentum Sensor, Impact Plasma & Momentum Sensor, Capacitor Impact Sensor	2.23	1.9	361	903	-	J. A. M. McDonnell Space Sciences Laboratory University of Kent Canterbury UK	MPI für Kernphysik, Heidelberg; ONERA/CERTS/DERTS, Toulouse; ESA Space Science Department;
Plasma Analysis 1	Fast Ion Sensor, Implanted Ion Sensor	4.7	4.359	3975	1265	1355	A. Johnstone Mullard Space Science Lab. Holmbury St. Mary UK	MPI für Aeronomie, Lindau; Istituto Plasma Spaziale, Frascati;
Plasma Analysis 2	Electron Electrostatic Analyser, Positive Ion Cluster Composition Analyser	3.151	3.7	2530	1807	904	H. Rème Centre d'Etude Spatiale des Rayonnements Toulouse France	MPI für Aeronomie, Lindau; Space Sciences Laboratory, Berkeley;
Energetic Particles		0.679	0.7	181			S. M. P. Mckenna-Lawlor St. Patrick's College Maynooth Ireland	Dublin Institute for Advanced Studies; MPI für Aeronomie, Lindau;
Magnetometer		1.358	1.2	1265		407	F. M. Neubauer Institut für Geophysik und Meteorologie, Köln W. Germany	Institut für Geophysik und Meteorologie, Braunschweig; Laboratory for Extraterrestrial Physics NASA/GSFC; Istituto di Fisica, University of Rome;
Optical Probe Experiment		1.32	1.0	723		-	A. C. Levasseur-Regourd Service d'Aeronomie du CNRS Verrières-le-Buisson France	Laboratoire d'Astronomie Spatiale, Marseille; Space Astronomy Laboratory, University of Florida, Gainesville;
TOTAL		57.43	53.71	39393		4654		

* Format 1: from t_0 - 4 hrs until t_0 - 1 hr
Format 2: from t_0 -1 hr until mission end
Format 3: during cruise and pre-encounter

THE COMETARY FLEET

Besides ESA, three other space agencies: Intercosmos of the USSR Academy of Sciences, the Japanese Institute of Space and Astronautical Science (ISAS) and NASA have prepared space missions to study Halley's Comet (see table below).

Key Data on missions to Halley's Comet

Agency	Project	Launch date	Flyby date	Flyby distance
ESA	Giotto	2 July 1985*	13 March 1986	500 km
Intercosmos	Vega-1	15 Dec. 1984	6 March 1986	10 000 km
	Vega-2	21 Dec. 1984	9 March 1986	10 000 km (possibly less)
ISAS	Sakigeke	8 Jan. 1985	11 March 1986	7 mill. km
	Planet-A	14 Aug. 1985*	8 March 1986	200 000 km
NASA	ICE	22 Dec. 1983**	28 March 1986	32 mill. km

* Planned launch date

** Lunar swingby manoeuvre to inject ICE (International Cometary Observer, formerly ISEE-3) into a heliocentric trajectory to Comet Giacobini-Zinner (flyby on 11 September 1985, 10 000 km on the antisunward side). If ICE survives the Giacobini-Zinner encounter, it will continue its interplanetary journey towards Halley's Comet which it will come closest to on 28 March 1986.

The different missions are complementary in instrumentation and flyby distances. They extend the total time of in-situ observations in the cometary environment and provide simultaneous observations from two or more spacecraft during certain time periods.

THE GIOTTO GROUND SEGMENT

The Giotto Operations Control Centre will be located at ESA's Space Operations Centre. ESOC, in Darmstadt, West Germany and telemetry, telecommand and tracking facilities all over the world will be used during different mission phases:

Geostationary Transfer Orbit (GTO) Near Earth Phase (NEP)	ESA GTO Network comprising the Malindi, Kourou and Carnarvon stations. Weilheim (DFVLR) NASA Deep Space Network(DSN) stations at Goldstone, Madrid and Tidbinbilla
Cruise Phase	Carnarvon
Rehearsals	Weilheim
Encounter	The Parkes Radio Telescope in Australia NASA Deep Space Network

ESOC has procured, integrated and tested ground station equipment for many of these sites which will be tested on site during the coming months. The control rooms, computers, software and flight operations documents were prepared and tested at ESOC and a series of mission simultations took place in May and June 1985. During the final stages of the cruise phase, just prior to Giotto's encounter with Halley's Comet, the USSR Intercosmos Space Agency will provide ESA with information from its Vega spacecraft on the position of the Comet's nucleus, thus enabling ESOC to target the spacecraft with the best possible degree of accuracy.

GIOTTO OPERATIONS

The Ariane launcher will place Giotto into a Geostationary Transfer orbit from the Kourou launch site. Following separation from the launcher third stage, mission control right up to the encounter will be conducted from the ESOC Operation Control Centre.

GEOSTATIONARY TRANSFER ORBIT (GTO) AND NEAR EARTH PHASE (NEP)

After 3 revolutions in the GTO, a solid rocket motor on the spacecraft will be fired to inject it into an earth escape trajectory which is designed for intersection with the orbit of Halley's comet some 8 months later. Immediately following injection, an intensive campaign of tracking will ensue to determine accurately the achieved orbit. The first trajectory correction manoeuvre will then take place within 2-3 days. Another important operation during this period will be establishing the communications link with Giotto via its High Gain Directional Antenna which must then be maintained in an Earth-pointing mode for the remainder of the mission.

CRUISE, REHEARSAL PHASES

Once these operations are completed, the spacecraft enters a cruise phase lasting 8 months. Daily contact will be established to check the health of the on-board systems and to perform fine attitude manoeuvres and trajectory correction manoeuvres. A series of rehearsals is planned during October 1985, January and February 1986 to switch-on and check-out the experiments and rehearse the Encounter operations. A final "Dress Rehearsal" will take place a few days prior to closest approach.

ENCOUNTER

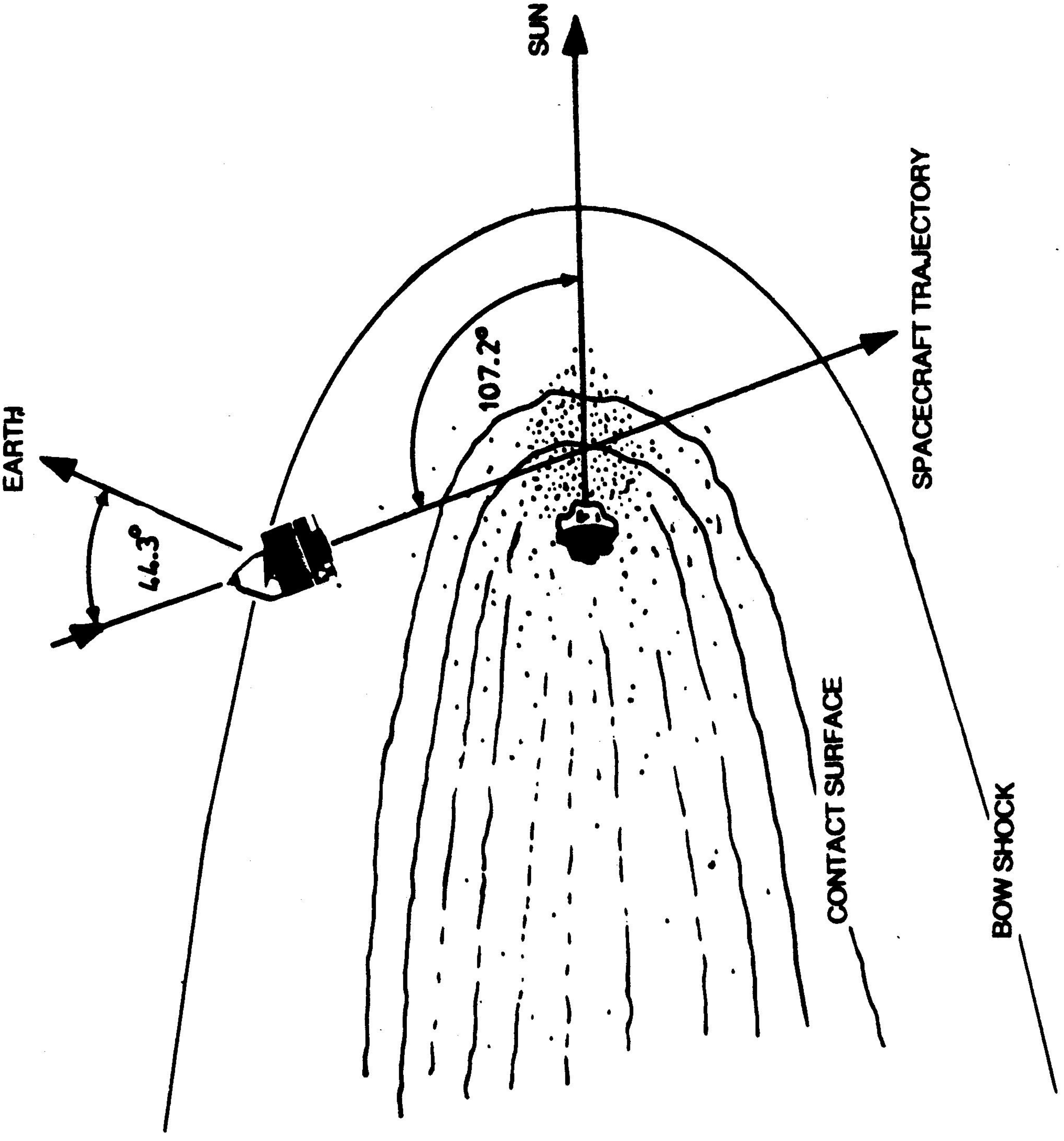
The Encounter itself will take place around midnight (GMT) on March 13 1986. The payload and subsystems will be configured for a 4 hour high-speed data take over Australia using the Carnarvon station (commanding) and the 64-metre Parkes Radio Telescope dish (telemetry reception). The Deep Space Network station at Tidbinbilla (Australia) will be in hot back-up to support this phase. It is not expected that the spacecraft will survive beyond the point of closest approach to the comet.

THE INTER-AGENCY CONSULTATION GROUP (IACG)

Realising that many aspects of mission planning, spacecraft and experiment design and data evaluation are common to all missions, and that the overall scientific return could be increased through cooperation, the four Agencies agreed, in 1981, to form the Inter-Agency Consultative Group (IACG). The IACG has the task of informally coordinating all matters related to the space encounter and near-Earth space observation missions to Halley's Comet, whereas all ground-based observations are coordinated by the International Halley Watch (IHW).

At the first meeting of the IACG which took place on 13-15 September 1981 in Padova, Italy numerous details on the various space missions were exchanged for the first time and the general principles of cooperation were established. Three working groups were formed in which many of the problems common to all space missions to Halley's Comet are discussed, resulting in recommendations to the flight projects or actions to carry out specific tasks. The three working groups are:

- the Halley Environment Working Group (WG-1)
- the Plasma Science Working Group (WG-2)
- the Spacecraft Navigation and Mission Optimisation Working Group (WG-3)


SUN
EARTH
107.2°
44.3°
SPACECRAFT TRAJECTORY
CONTACT SURFACE
BOW SHOCK

The second meeting was held in Dobogokö (Hungary) on 21-22 November 1982. At the third meeting in Kagoshima (Japan) on 18-19 December 1983, Working Group N° 3 was dissolved and replaced by a "Pathfinder Implementation Group". The pathfinder concept allows Giotto to be targetted more precisely, thanks to the navigational support provided by Intercosmos. The fourth meeting of the IACG took place in Tallinn (USSR) in October 1984, the fifth meeting will be held in Washington (USA) on 10-13 September 1985, on the occasion of the Giacobini-Zinner fly-by and the last meeting will again be held in Padova on 3-4 November 1986 immediately after the Heidelberg Conference (27-31 October 1986) at which all the results from the space mission and from the ground-based observations will be presented.

The IACG Delegations from the four space agencies are headed by :

ESA :	R.M. Bonnet, Director of Scientific Programmes
NASA :	G.A. Briggs, Director of Solar System Exploration Division of the Office of Space Science and Applications
INTERCOSMOS :	R.Z. Sagdeev, Director of the Space Research Institution of the Academy of Sciences of the USSR
ISAS :	K. Hirao, Director of the Office of External Relations

THE INTERNATIONAL HALLEY WATCH (IHW)

The aims of the IHW are to stimulate, encourage and coordinate scientific observations throughout the whole apparition to ensure that observing techniques and instrumentation are standardised wherever possible, to distribute data to participating scientists and provide information to the public and media and to help ensure that the data and results are properly documented and archived.

The most important elements in the IHW are the Professional Observers and the Discipline Specialists (DS) teams. Experts have been selected for eight DS teams in each of the eight areas of astronomical technology: astrometry, infrared spectroscopy & radiometry, large-scale phenomena, near-nucleus studies, photometry & photopolarimetry, radio studies, spectroscopy & spectrophotometry and meteor stream studies. A Lead Centre Organisation has been set up to coordinate activities among the various disciplines and between the various flight projects. The Lead Centre Organisation has set up two offices, one in Pasadena, USA (Western Hemisphere Office, Leader: R.L. Newburn) and one in Bamberg, Germany (Eastern Hemisphere Office, Leader: J. Rahe). The Lead Centre Organisation also coordinates amateur observation activities and will store all Halley data and, ultimately, produce the Halley archive. An IHW Steering Group serves in an advisory capacity to the Lead Centre Organisation, making available a vast store of experience in the problems of cometary science and international cooperation. Cooperation of the flight projects with the IHW is achieved through the Project Representatives designated by each flight project to serve as single-path communication links. The flight projects will supply their scientific results to the Halley Archive and will support the ground-based efforts of the IHW. At present, about 800 professional and more than 3000 amateur observers participate in the IHW.

INDUSTRIAL MANAGEMENT

British Aerospace Dynamics Group Space and Communications Division were appointed prime contractor by the European Space Agency for the Giotto spacecraft in December 1982. Since then British Aerospace has successfully managed a team of specialist contractors from ten European countries working within the STAR consortium, in the design, development and testing of Giotto - Europe's first deep space explorer. The completed spacecraft was formally accepted from British Aerospace by the European Space Agency at CNES Toulouse on 23 April 1985.

British Aerospace and the team of contractor companies embarked upon initial studies of this unique programme in 1978. During 1981 - 82 the overall project was defined which led the way to developing the numerous subsystems in 1982 - 84. To manage the programme most efficiently major reveiws were held with the European Space Agency throughout. These were the :

System Design Review, February 1982
Hardware Design Review, June 1983
Final Design Review, January 1984
Flight Acceptance Review, March 1985

Testing of the structural model of the spacecraft commenced at IABG Ottobrunn, Munich in the Spring of 1982. The main purpose of these tests was to demonstrate the adequacy of the design and structural integrity prior to commencement of work on the flight model structure. The second model in the programme, the electrical model, proved the compatibility of the interfaces and verified the basic system design concept. This was done at Bristol between the end of May 1983 and January 1984. At the end of this part of the programme, British Aerospace had fully tested the electrical model spacecraft, had confirmed its electromagnetic compatability characteristics and had developed the procedures which would sub-sequently be used on the flight spacecraft. As a result of achieving this major milestone there was confidence to proceed in early 1984 with the integration of the flight spacecraft.

All went well, and Giotto left Bristol in June, following integration, to begin its environmental test programme using the comprehensive facilities at INTESPACE, CNES, Toulouse. During this phase of the programme the solar simulation test explored the performance of the thermal control subsystem and its interaction with the rest of the spacecraft whilst simulating the most extreme conditions to be expected during the 8-month mission to the Comet. In the thermal vacuum test Giotto was similarly pushed to the extremes of its anticipated thermal environment and satisfactory performance was confirmed. Individual system level tests were then completed by acoustic random vibration and sine vibration tests. Finally specialised demagnetisation tests were carried out by IABG Munich to ensure that the spacecraft was magnetically clean.

On return of Giotto to INTESPACE, CNES, equipment refurbishment and exchanges and final mechanical checks were made. Completion of the environmental test programme and acceptance of the spacecraft by the European Space Agency concluded British Aerospace's role as prime contractor. The company continues to support the Agency for the duration of the launch campaign.

Shipment from Toulouse to the launch site in Kourou, French Guiana, took place on the 28th April. The launch campaign lasting for two months is split into 3 phases, the first being the spacecraft preparation that will include further electrical testing. The second phase is the hazardous operation of loading the reaction control system with hydrazine and installation of the transfer propulsion system motor and finally on the gantry, mating the spacecraft to the launch vehicle and final checks prior to launch.

GIOTTO CONTRACTOR TEAM

CO. CONTRACTORS	COUNTRY	RESPONSIBILITY
AEG Telefunken	FR Germany	Solar Array
BTM	Belgium	Pryothechnic electronic unit
Dornier System GmbH	FR Germany	Structure, antenna attitude and orbit control system
ETCA	Belgium	Electrical ground support equipment
FIAR	Italy	Power Supply
Fokker	Netherlands	Thermal control system
Laben	Italy	On-board data handling
SEP (Bordeaux)	France	Transfer propulsion system
SEP (Vernon)	France	De-spin mechanism and de-spin control electronics
Alcatel-Thomson Espace	France	Telemetry tracking and command systems
ORS	Austria	Mechanical ground support equipment
British Aerospace	United Kingdom	Coordinate manufacture, assemble, integrate and test, supply and fit cable harness
Electronikcentralen	Denmark	Thermal control unit
SUBCONTRACTORS		
Contraves	Switzerland	Spacecraft structure
DFVLR	FR Germany	Plume impingement studies
MBB-ERNO	FR Germany	Reaction control electronics
Ericson	Sweden	Antenna system
Fokker	Netherlands	Nutation dampers, overall check-out equipment
Galileo	Italy	Earth and sun sensors
Laben	Italy	Power distribution equipment for attitude and orbit control systems
TPD	Netherlands	Star mapper

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